AN ATTEMPT To prove the MOTION OF THE EARTH FROM Obſervations

MADE BY

ROBERT HOOKE Fellow of the *Royal Society.*

Senec. Nat. Qu. lib. 1. cap. 30.

Nè miremur tam tardè erui quæ tam altè jacent.

LONDON,

Printed by *T. R.* for *John Martyn* Printer to the *Royal Society*, at the *Bell* in St. *Pauls* Church-yard. 1674.

AN

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To prove the

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EARTH

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at the Bell in St. Paul's Church-yard. 1674

TO THE

TRULY HONORABLE

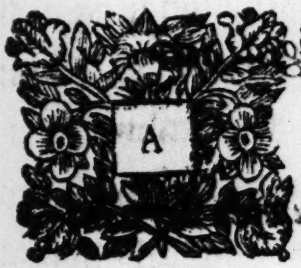
Sir John Cutler

KNIGHT and BARONET,

My Worthy

PATRON.

SIR,



AMong several Eminent Marks of your Greatness of Mind for promoting the Publick Good, that of your Bounty for the Advancement of *Experimental* and *Real Knowledge*, by the Founding a *Physico-Mechanical Lecture*,

deserves to be Recorded as One, and more especially by me whom you have honoured by establishing your first *Lecturer*. As an Earnest of others more considerable shortly to follow, I here present you with one of my *Discourses* in that Employment, which though short and plain, conteins somewhat of *Information* which the *Learned* have hitherto desired, though almost with despair. As I hope their kind Acceptance will produce their thanks to you to whom they are justly due, so your Acceptance will incourage me in the further prosecution of these *Inquiries* to approve my self,

Noble Sir,

From *Gresham Colledge*,
March 25. 1674.

Your most obliged, and

most humble Servant

ROBERT HOOKE.

READER,

I *Have formerly in the Preface of my* Micrographia *given the World an account of the founding a* Phyſico-Mechanical Lecture *in the Year* 1665, *by Sir* John Cutler, *for the promoting the Hiſtory of Nature and of Art. In proſecution thereof I have collected many Obſervations both of the one and the other kind, and from time to time (as obliged) I have acquainted the* Royal Society *at their Publick Meetings, both at* Greſham College *and* Arundel Houſe *therewith, by* Diſcourſes *and* Lectures *thereupon.*

Now in order to the further promoting the End and Deſign of this Lecture, *I have complyed, with the deſire of ſeveral of my Friends (though otherwiſe not thereunto obliged) to commit divers of thoſe* Diſcourſes *to the Publick, though of themſelves for the moſt part incompleat, and* Eſſayes *or* Attempts *only upon ſeveral Subjects which have no dependencie or coherencie one with another. In the doing hereof, I deſign to avoid any kind of Method or Order that may require Apologies, Prefaces, or needleſs Repetitions of what is already known, or might have been ſaid upon that Occaſion, or may neceſſitate me to follow this or that Subject, that doth not ſome way or other offer it ſelf as it were, and*

prompt

prompt me to the consideration thereof. But because they may possibly admit of some better order hereafter, I design to print them all of the same Volume, that so they may be, when ranged, either stitched or bound together, and may, as occasion requires, be referred to under the Title of their Number and Page. This way I chuse as the best for promoting the Design of this Lecture; for as there is scarce one Subject of millions that may be pitched upon, but to write an exact and compleat History thereof, would require the whole time and attention of a mans life, and some thousands of Inventions and Observations to accomplish it: So on the other side no man is able to say that he will compleat this or that Inquiry, whatever it be, (The greatest part of Invention being but a luckey hitt of chance, for the most part not in our own power, and like the wind, the Spirit of Invention bloweth where and when it listeth, and we scarce know whence it came, or whether 'tis gone.) 'Twill be much better therefore to imbrace the influences of Providence, and to be diligent in the inquiry of every thing we meet with. For we shall quickly find that the number of considerable Observations and Inventions this way collected, will a hundred fold out-strip those that are found by Design. No man but hath some luckey hitts and useful thoughts on this or that Subject he is conversant about, the regarding and communicating of which, might be a means to other Persons highly to improve them. Whence 'twere much to be wished, that others would take this Method in their Publications, and not torment their Readers with such nauseous Repetitions, and frivolous

Apologies,

Apologies, as Method and Volumes do neceſſitate them to; But would rather inrich the Store-houſe of Art and Nature with choice and excellent Seed, freed from the Chaff and Droſs that do otherwiſe bury and corrupt it.

The communicating ſuch happy Thoughts and Occurrences need not much take up a mans time to fit it for the Preſs; the Relation being ſo much the better the plainer it is. And matter of Fact being the Kernel Readers *generally deſire (at leaſt in theſe Subjects) it will be ſo much the readier for uſe if it be freed from the thick and hard ſhell of Impertinences. This way alſo is more grateful both to the* Writer *and the* Reader, *who proceed with a freſh ſtomach upon variety, but would be weary and dull'd if neceſſitated to dwell too long upon one Subject. There are other conveniencies alſo in this Method of Communication not leſs conſiderable then the former, amongſt the reſt the ſecuring of Inventions to their firſt Authors, which 'tis hardly poſſible to do by any other means; for there are a ſort of Perſons that make it their buſineſs to pump and ſpy out others Inventions, that they may vend them to Traders of that kind, who think they do ingenuouſly to print them for their own, ſince they have bought and paid for them. Of this there have lately been ſome Inſtances, and more may be expected, if this way prevent not.*

When things cannot be well explained by words only (which is frequent in Mathematical *and* Mechanical Diſcourſes) *I adde Schemes and delineatious Deſcriptions of that kind being eaſier to be made and underſtood. As near as I can I omit the repeating things already printed,*

and

and indeavour to deliver such as are new and my own, being my self best pleased with such usage from other Authors.

I have begun with a Discourse *composed and read in* Gresham Colledge *in the Year* 1670. *when I designed to have printed it, but was diverted by the advice of some Friends to stay the repeating the Observation, rather then publish it upon the Experience of one Year only. But finding that Sickness hath hitherto hindered me from repeating the Tryals, and that some Years Observations have already been lost by the first delay: I do rather hast it out now, though imperfect, then detain it for a better compleating, hoping it may be at least a Hint to others to profecute and compleat the Observation, which I much long for.*

This first Discourse *is upon an Observation of Nature, and may therefore be properly referred to that Head, though it contein also somewhat of the Improvement of Art: The second speedily to follow, will more properly be referrable to* Artificial Improvements, *though it will contein also many Observations of Nature; and I design alwayes to make them follow each other by turns, and as 'twere to interweave them, being apart but like the Warp or Woof before contexture, unfit either to Cloth, or adorn the* Body of Philosophy.

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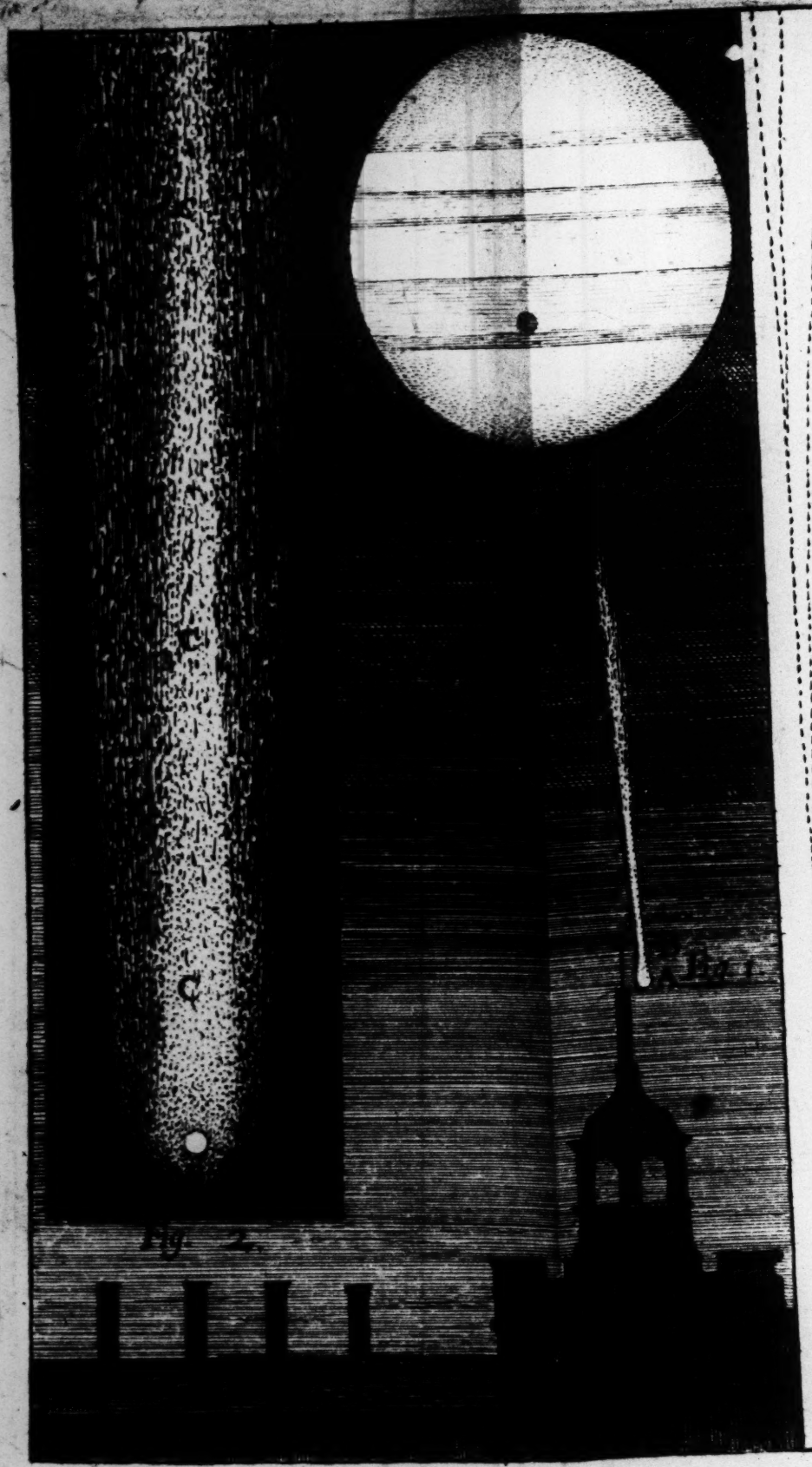
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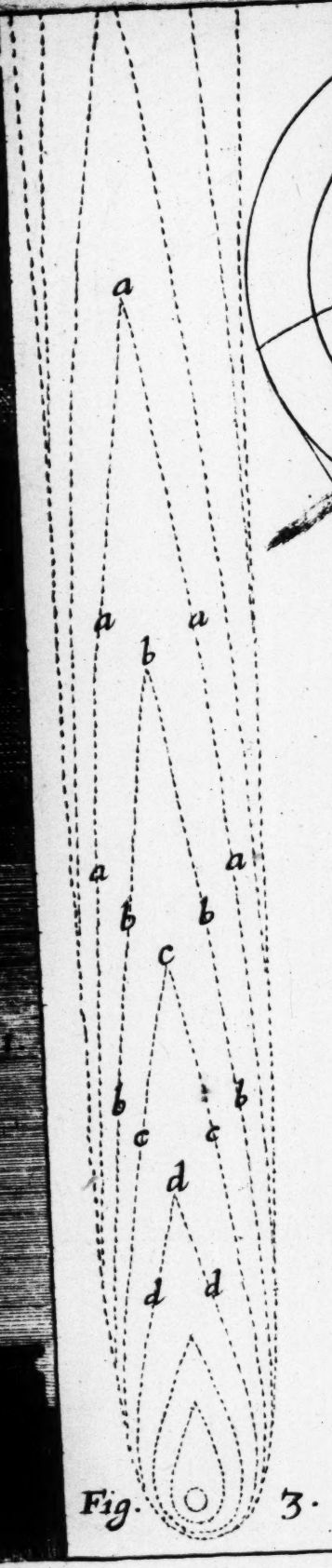
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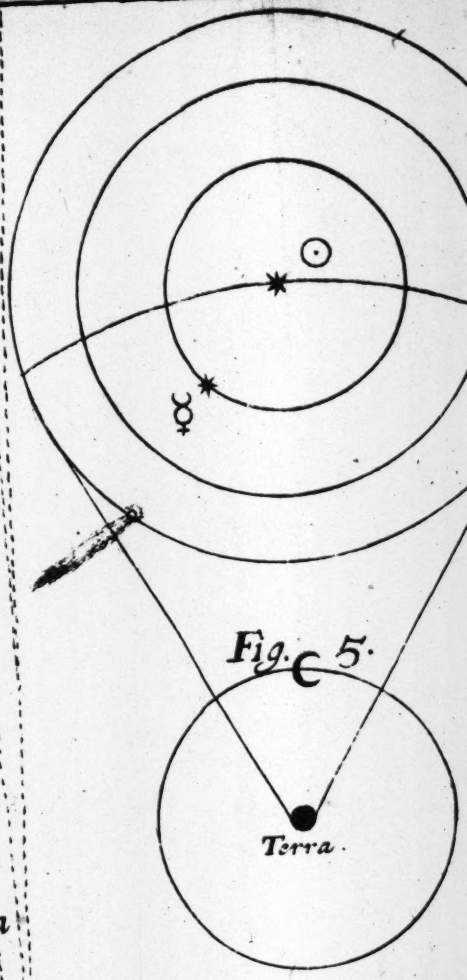
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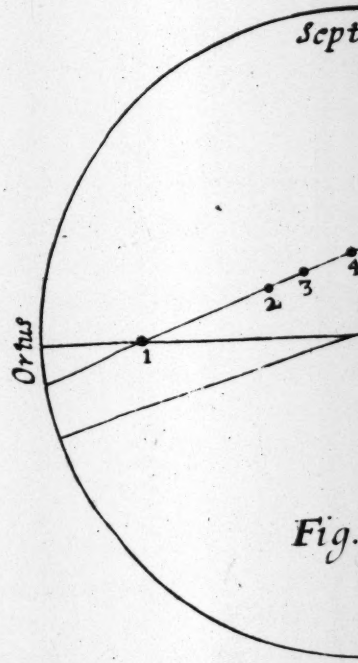
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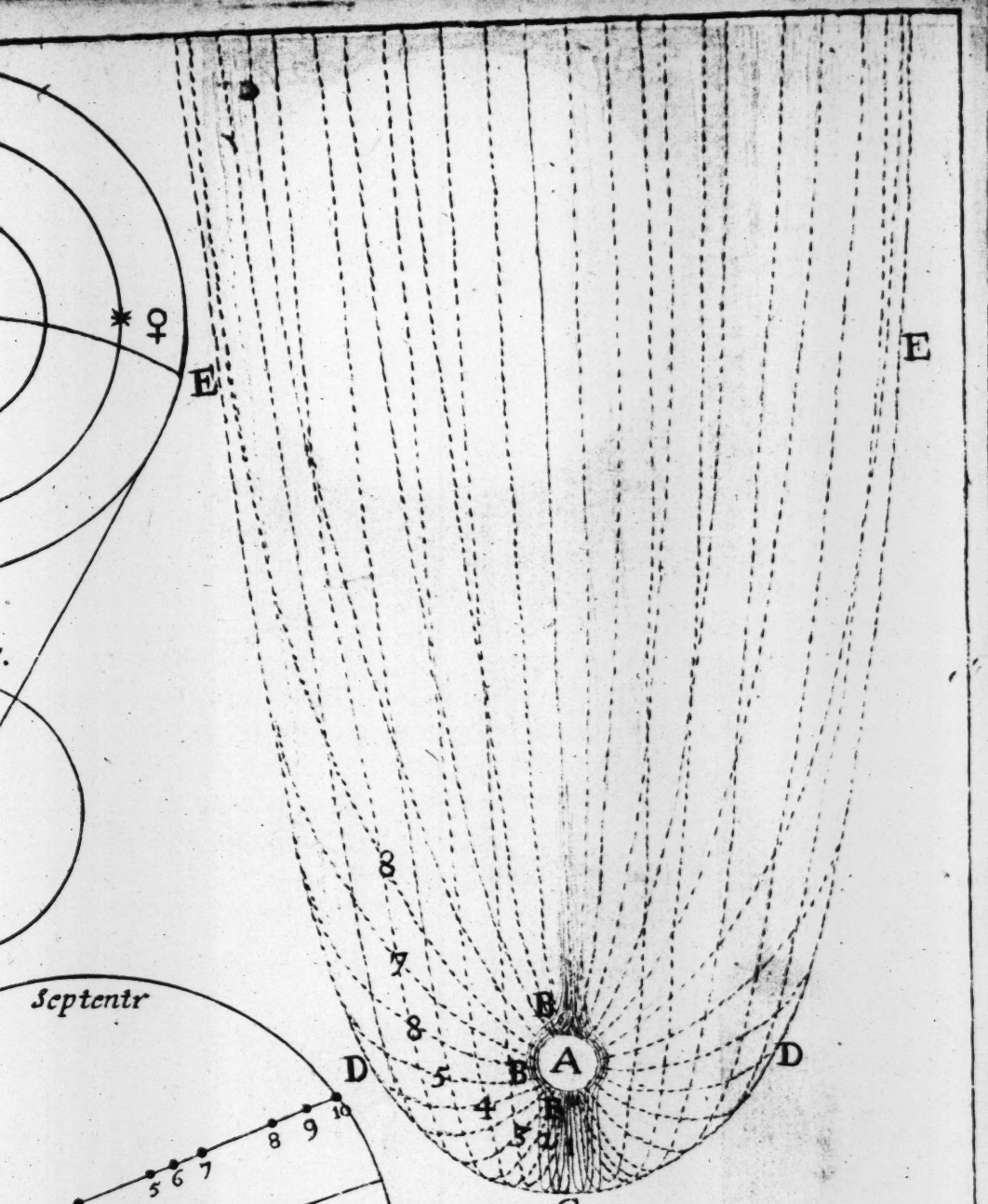

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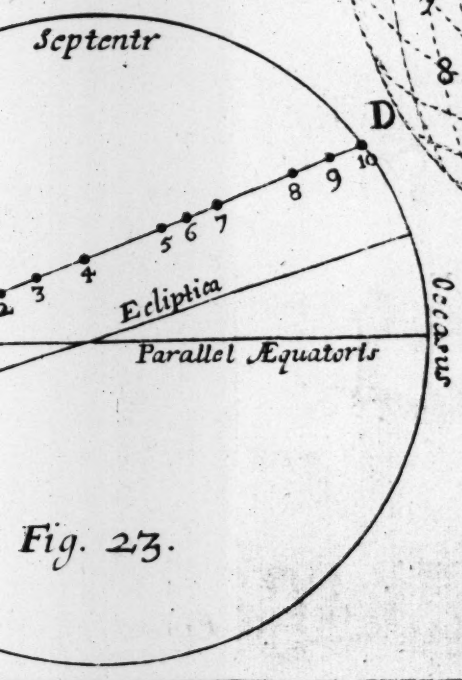

Fig. 23.

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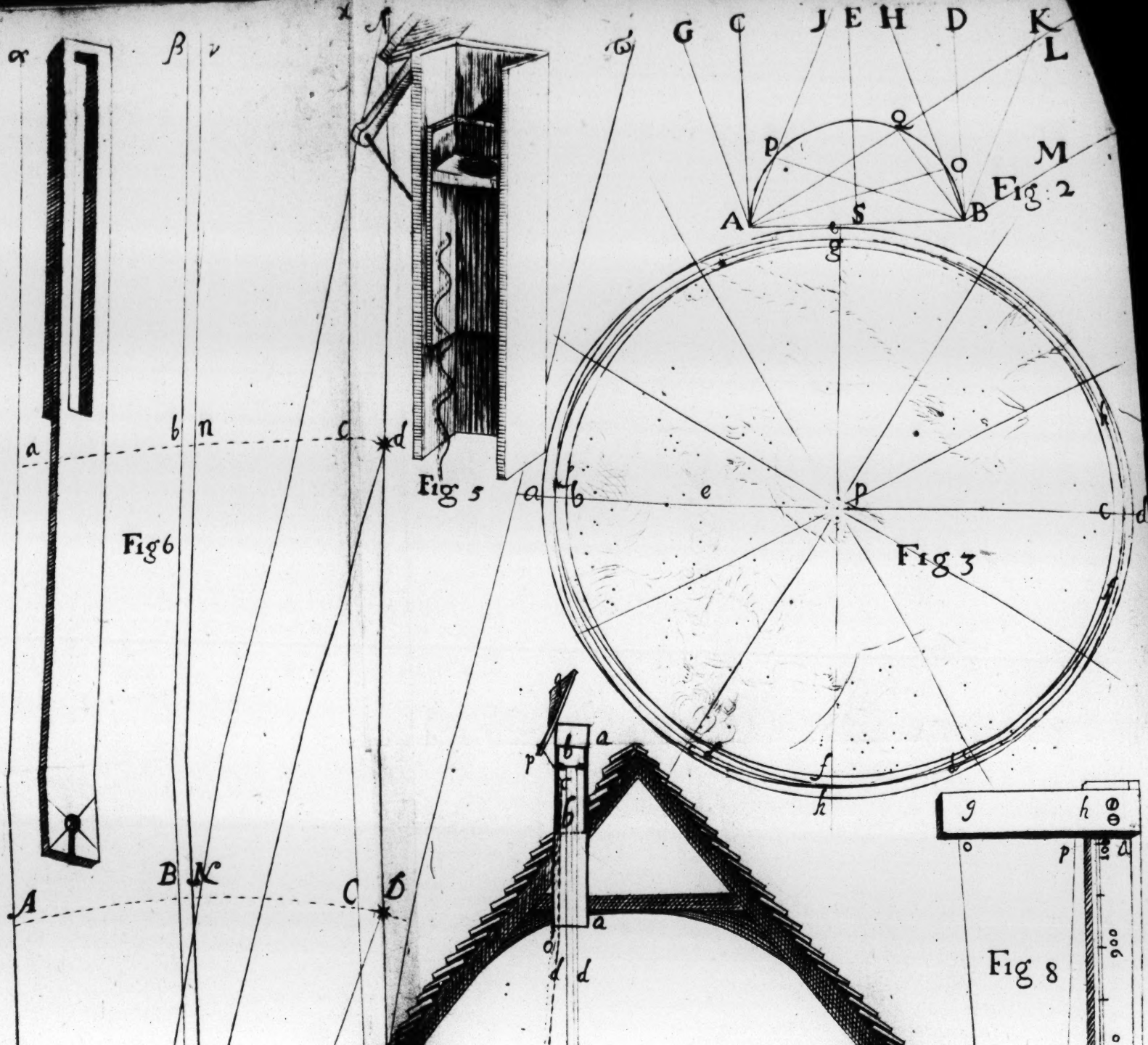
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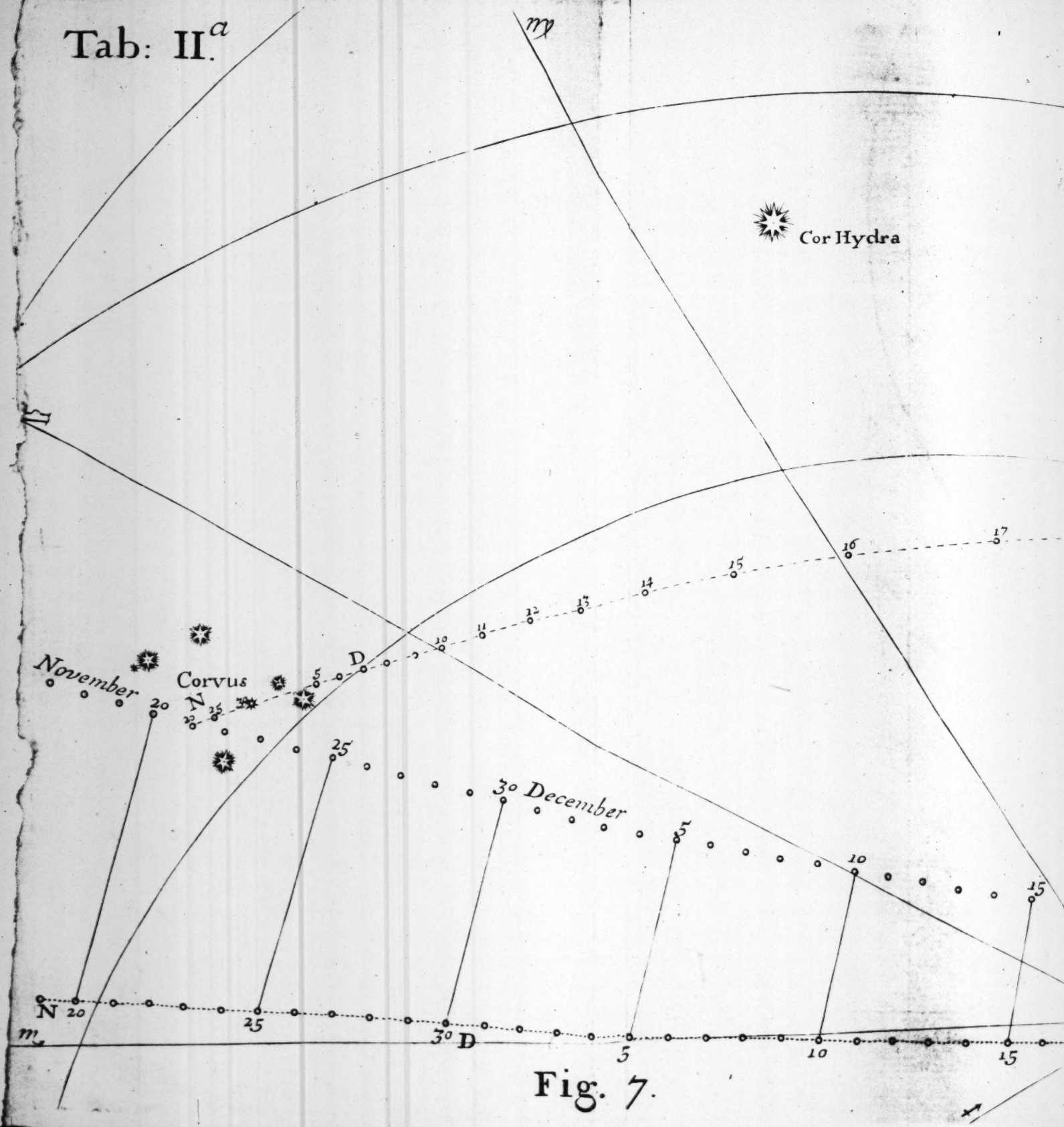

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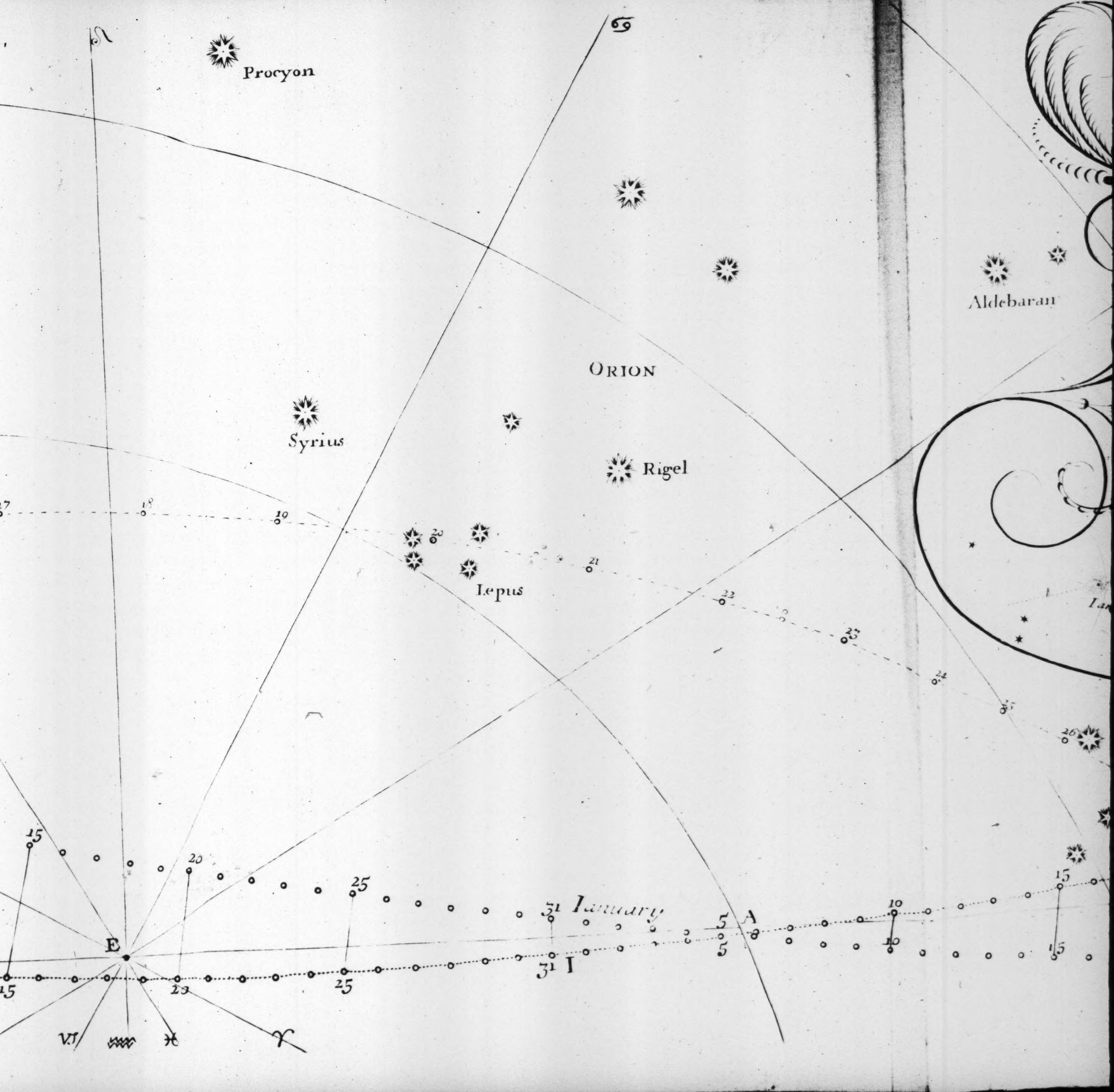

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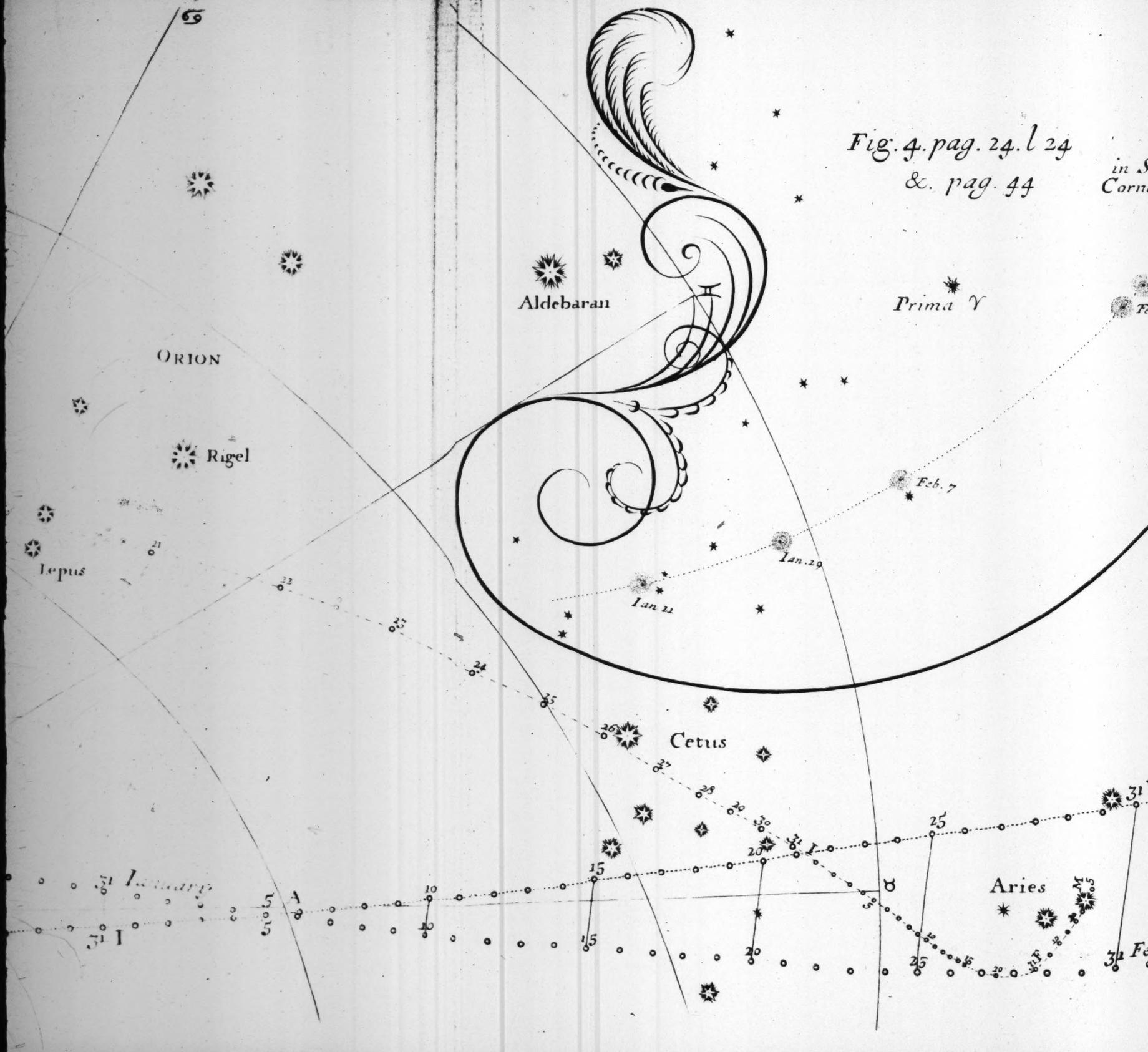
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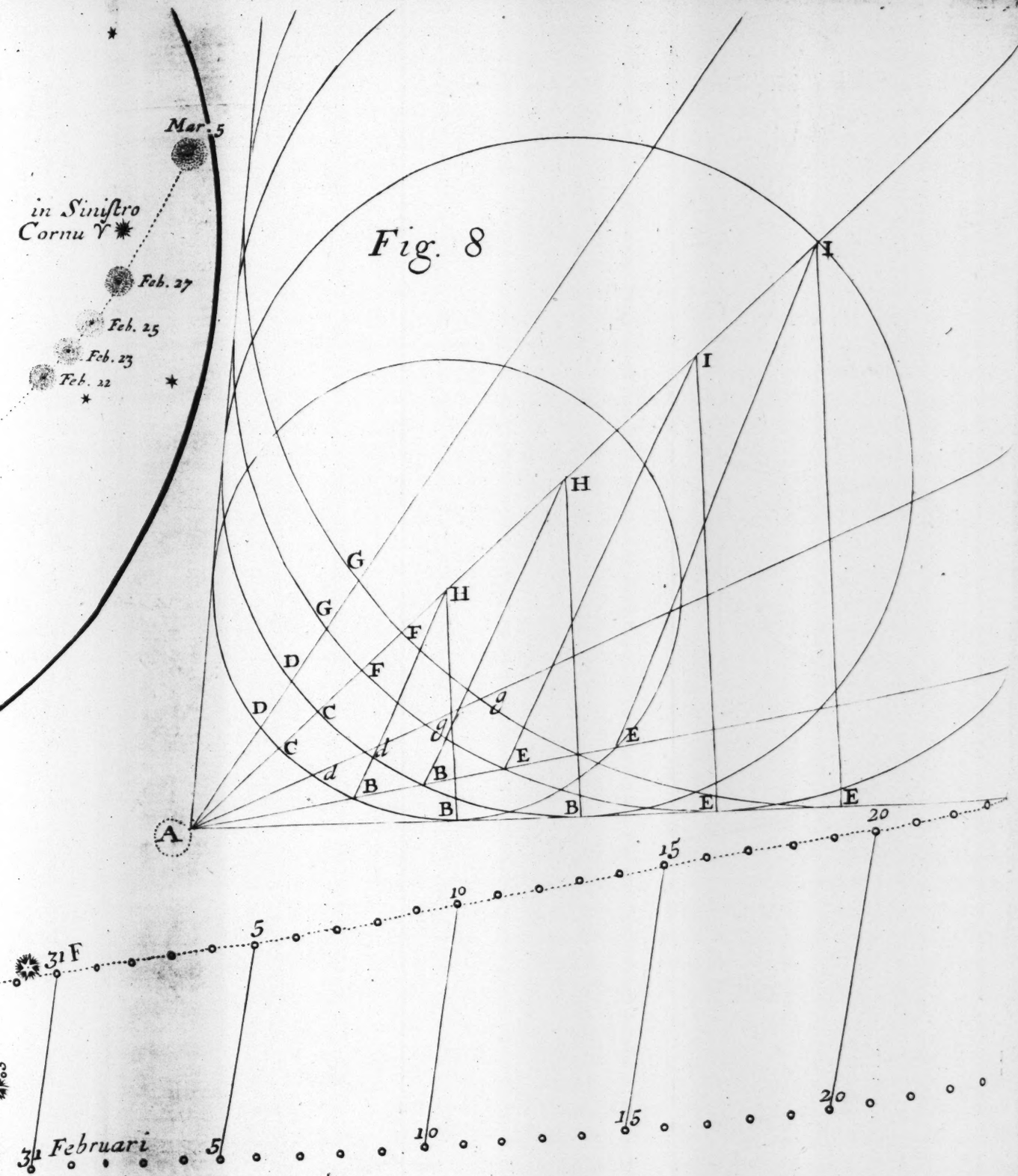
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Tab: III.[a]

Fig. VI pag. 26 l. 29

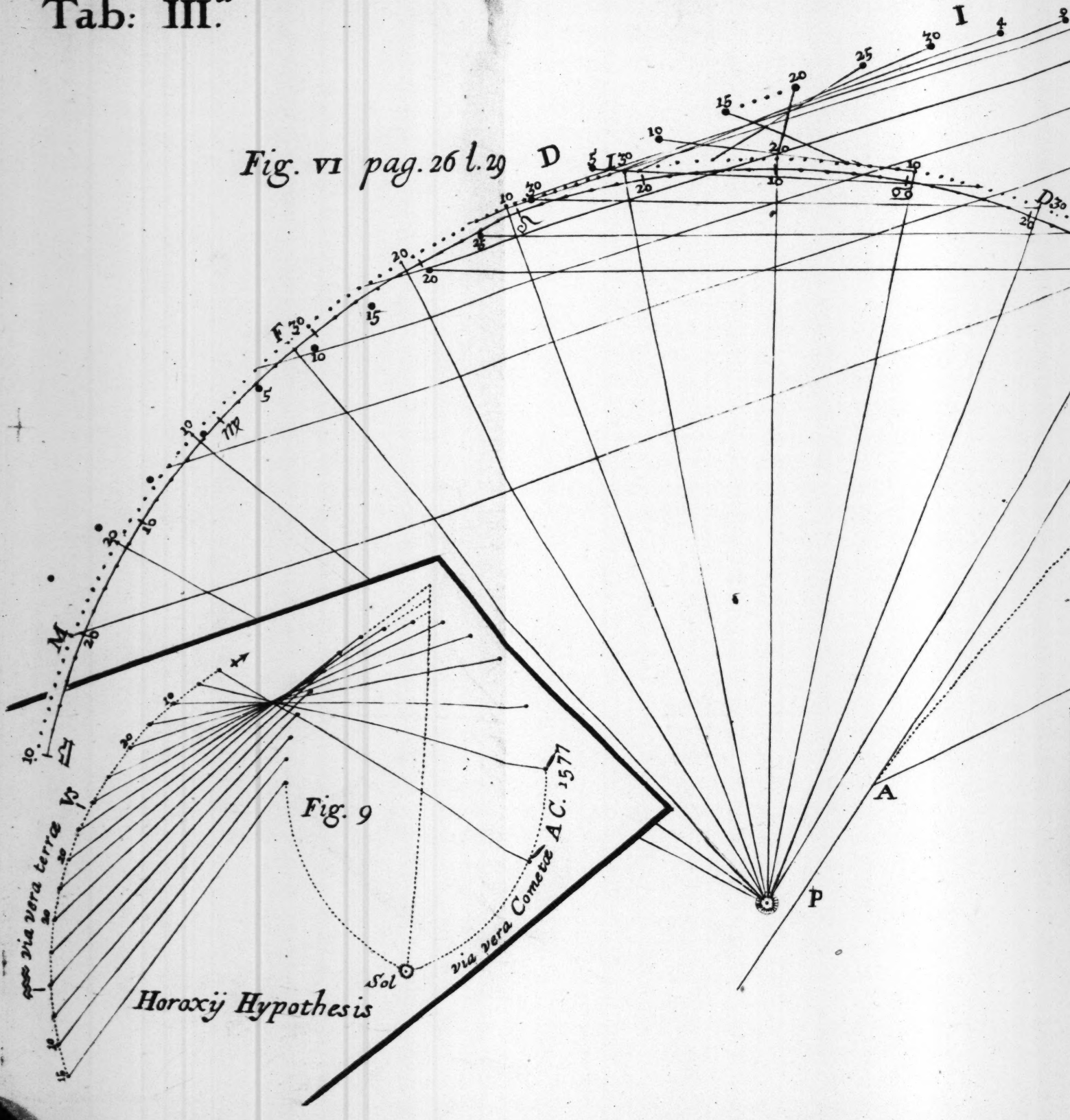

Fig. 9

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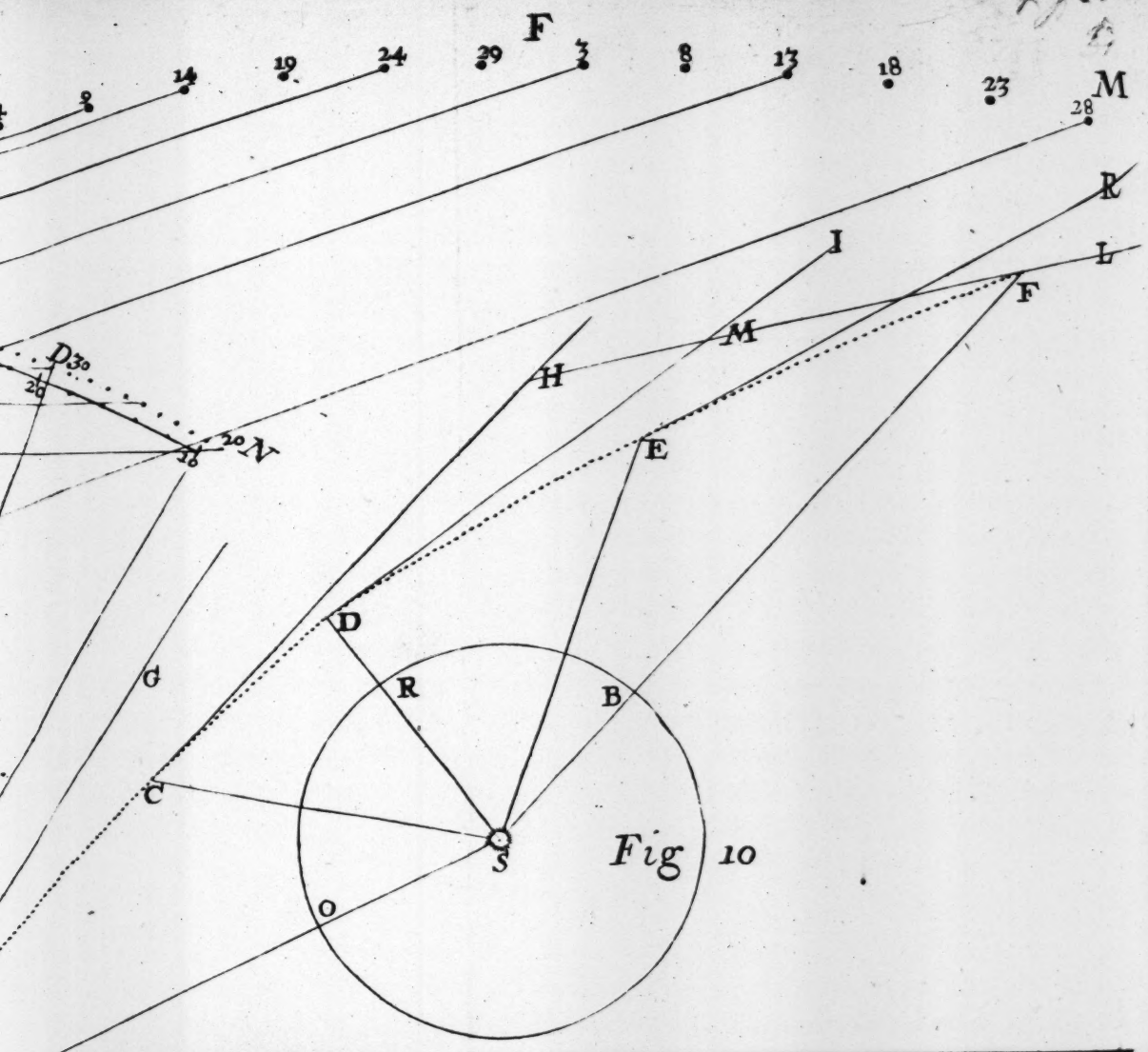
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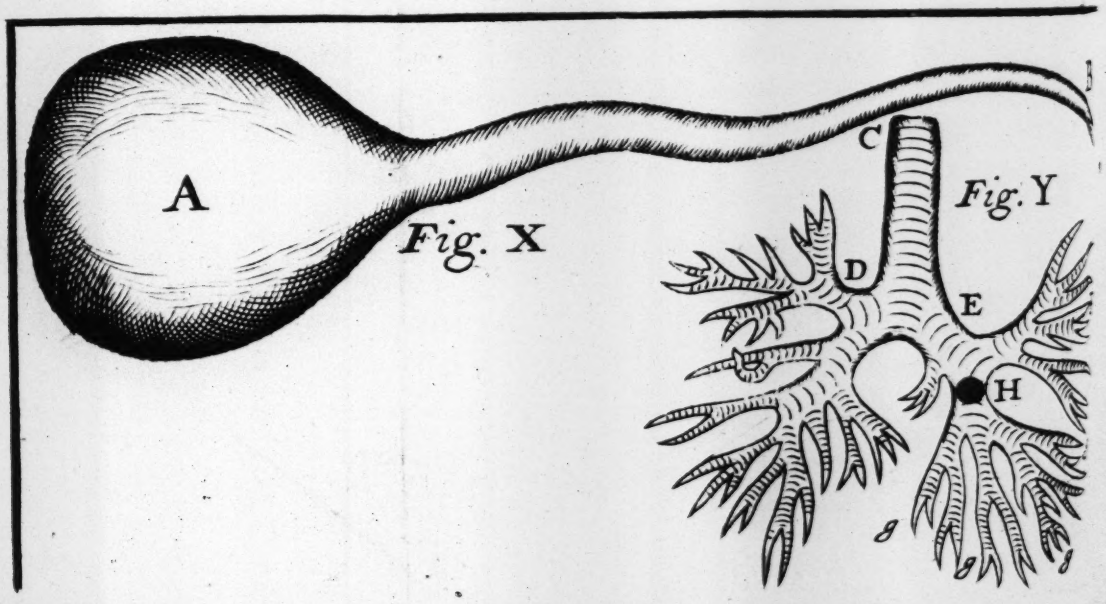
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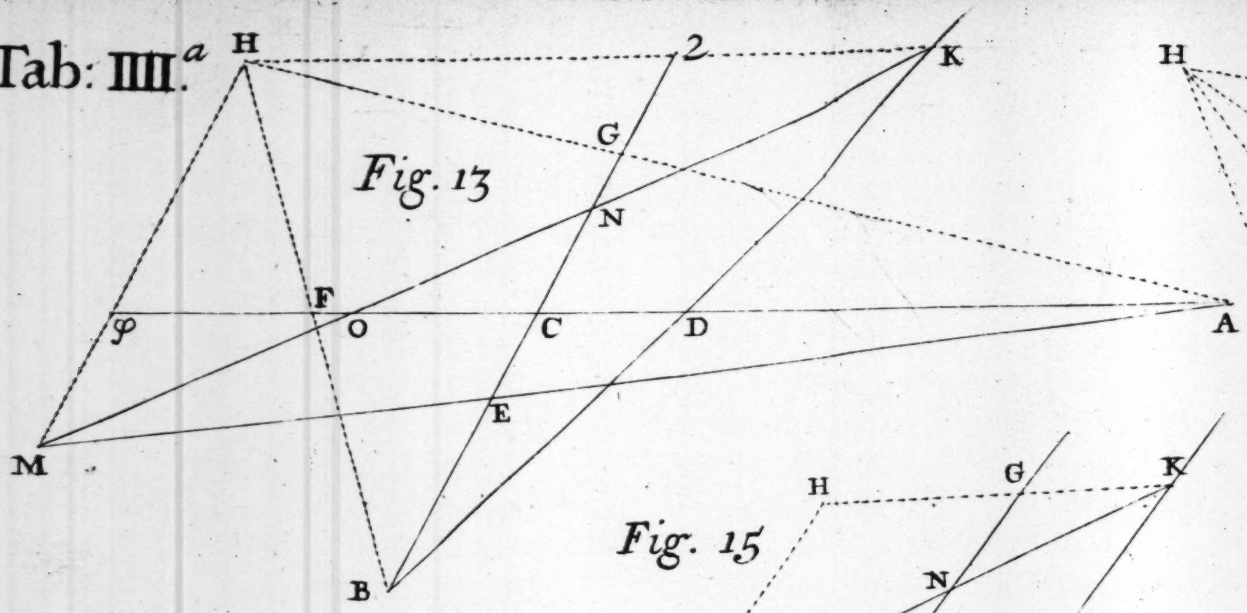


Fig. 13

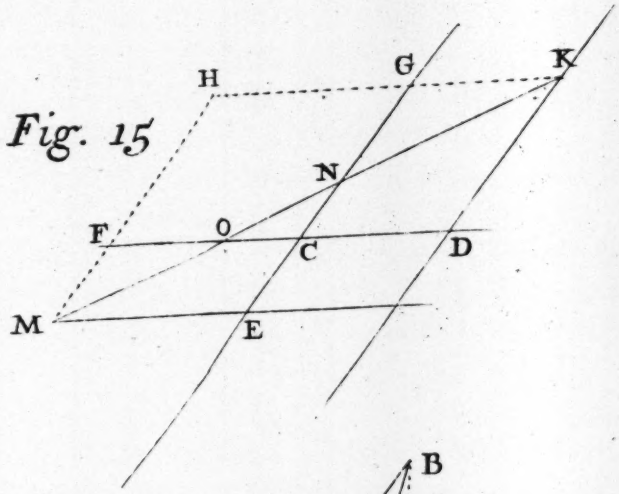


Fig. 15

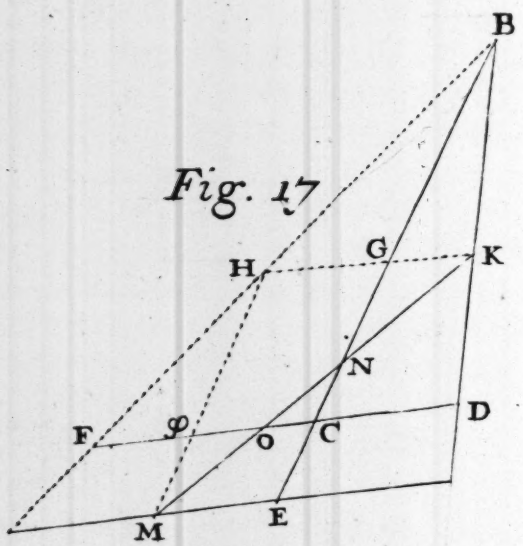


Fig. 17

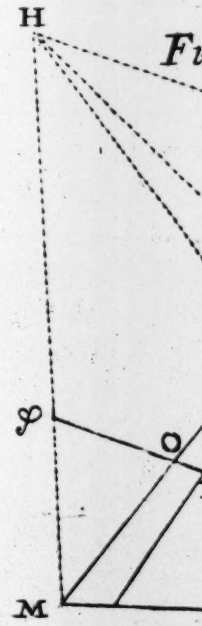


Fig. 18

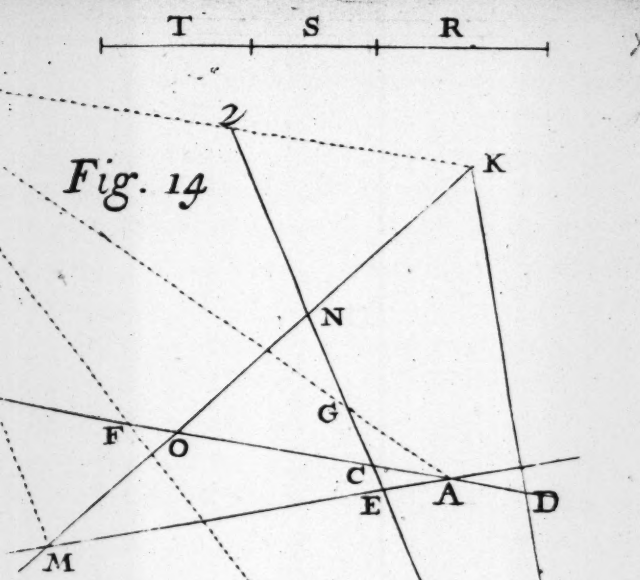


Fig. 14

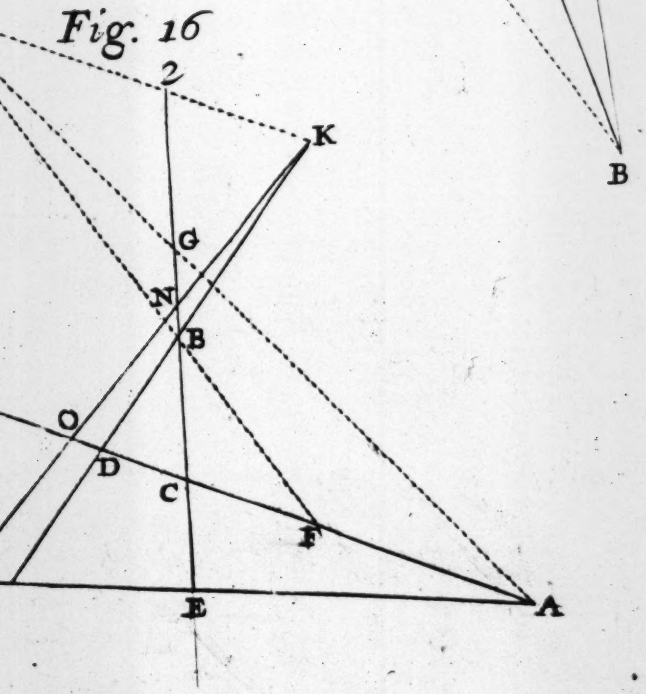
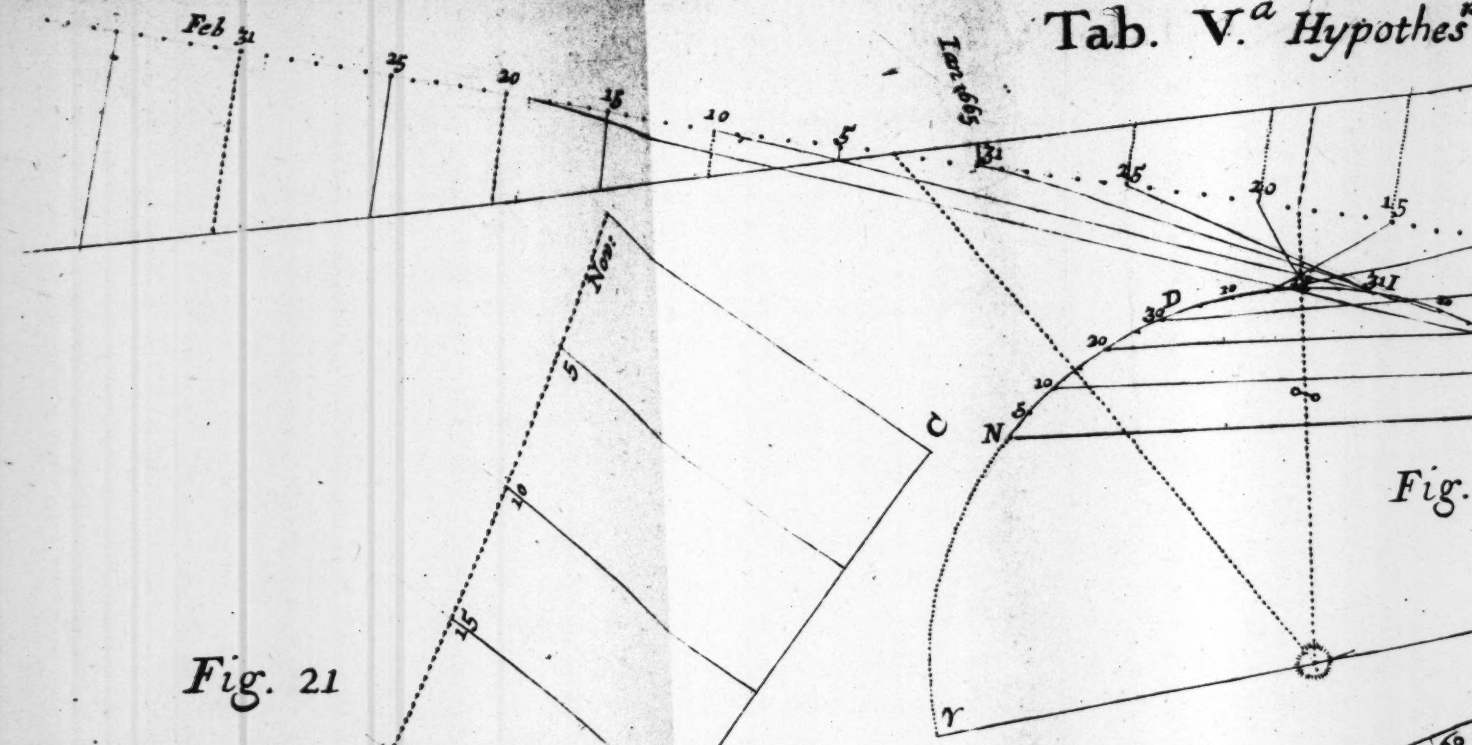


Fig. 16

Tab. V.a Hypothes



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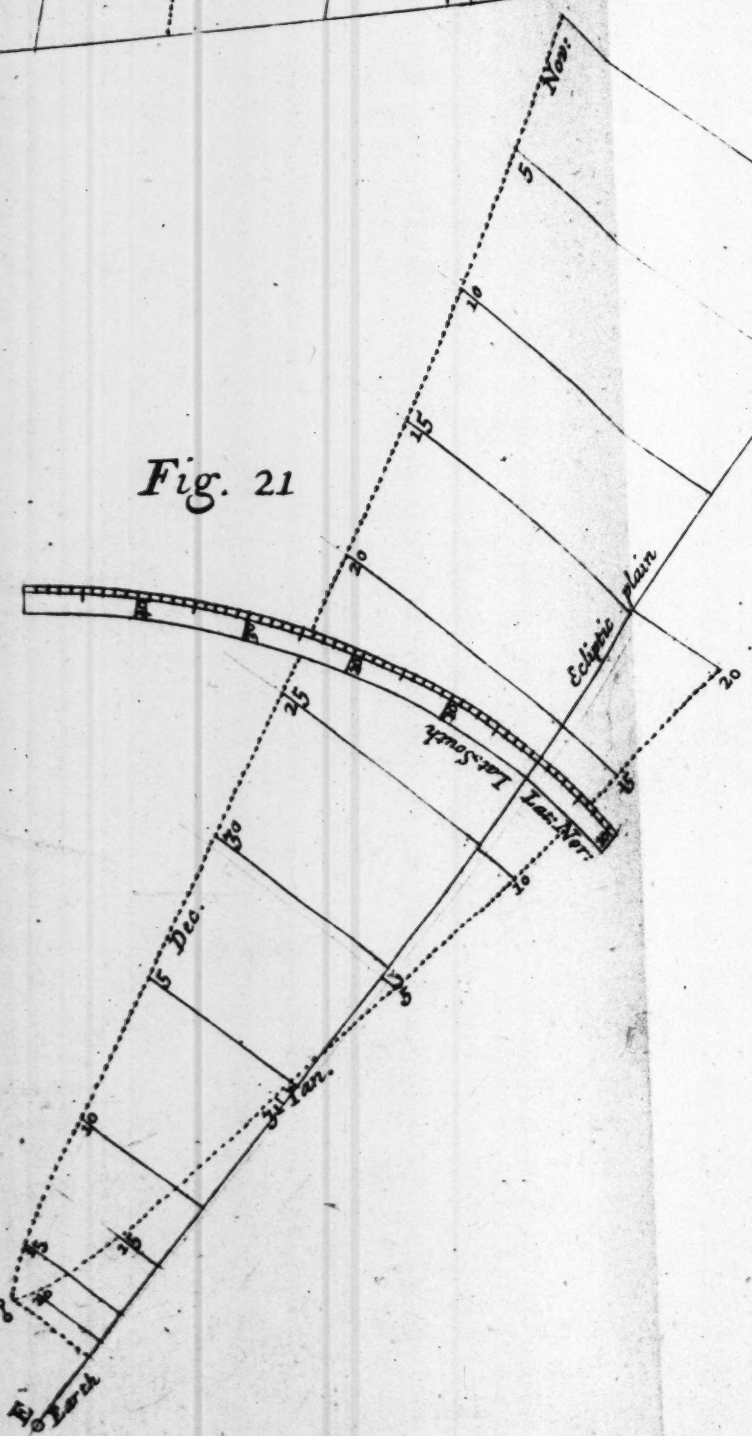

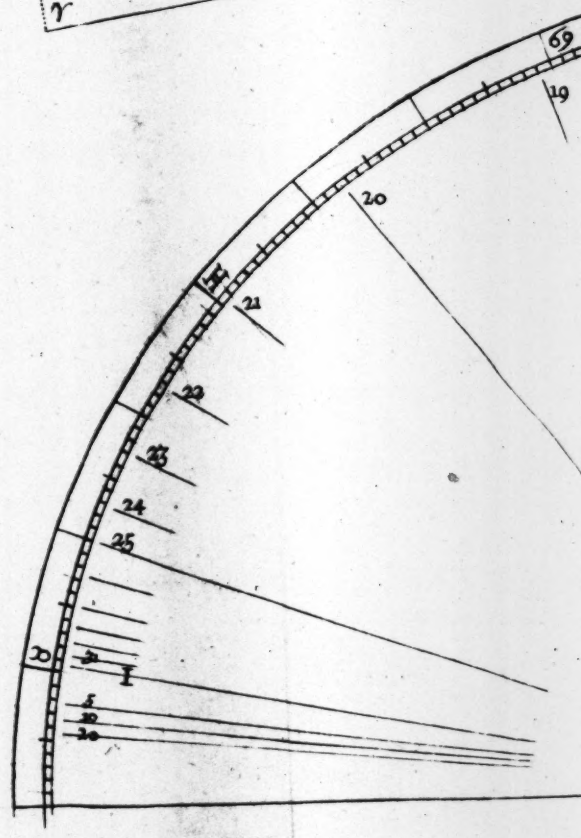

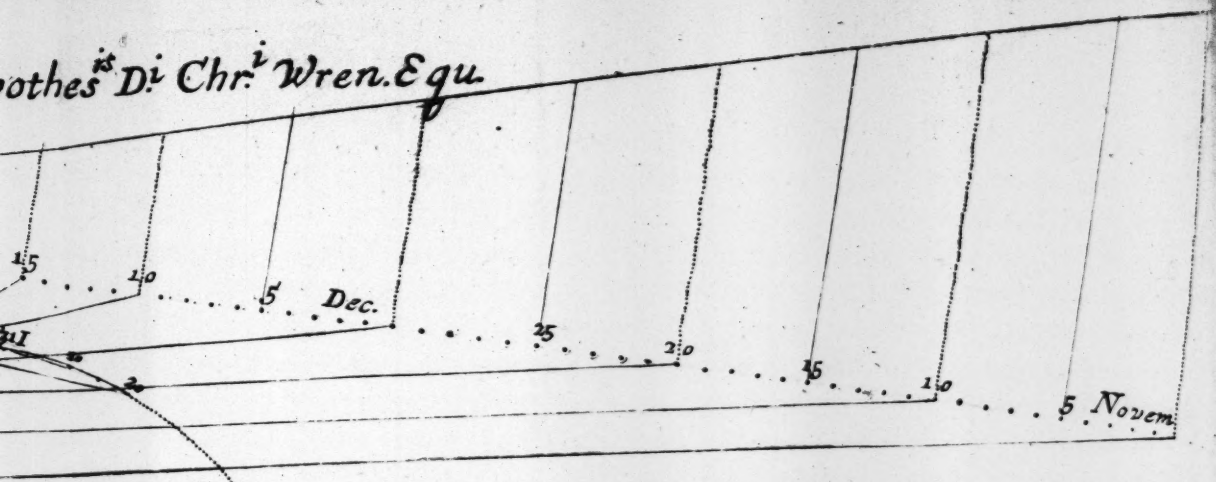

Fig. 19

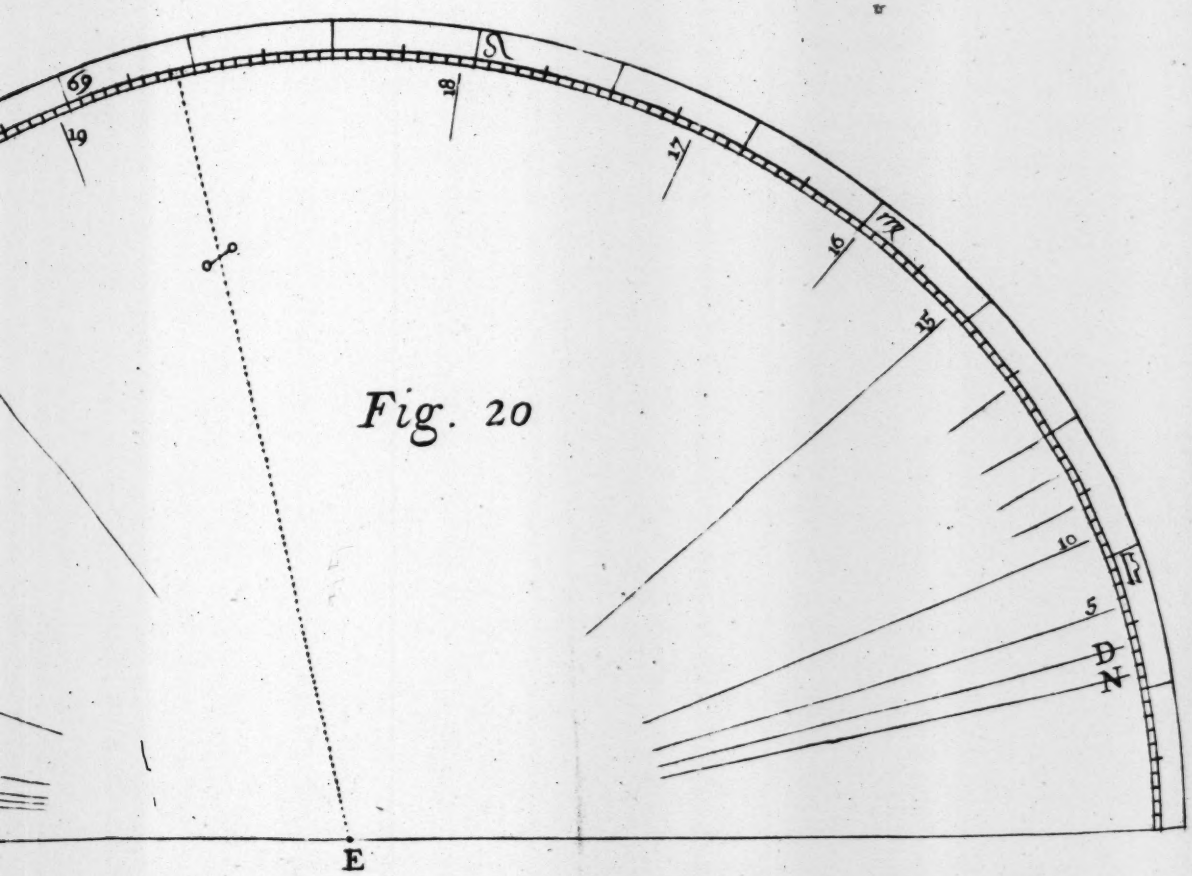

Fig. 20

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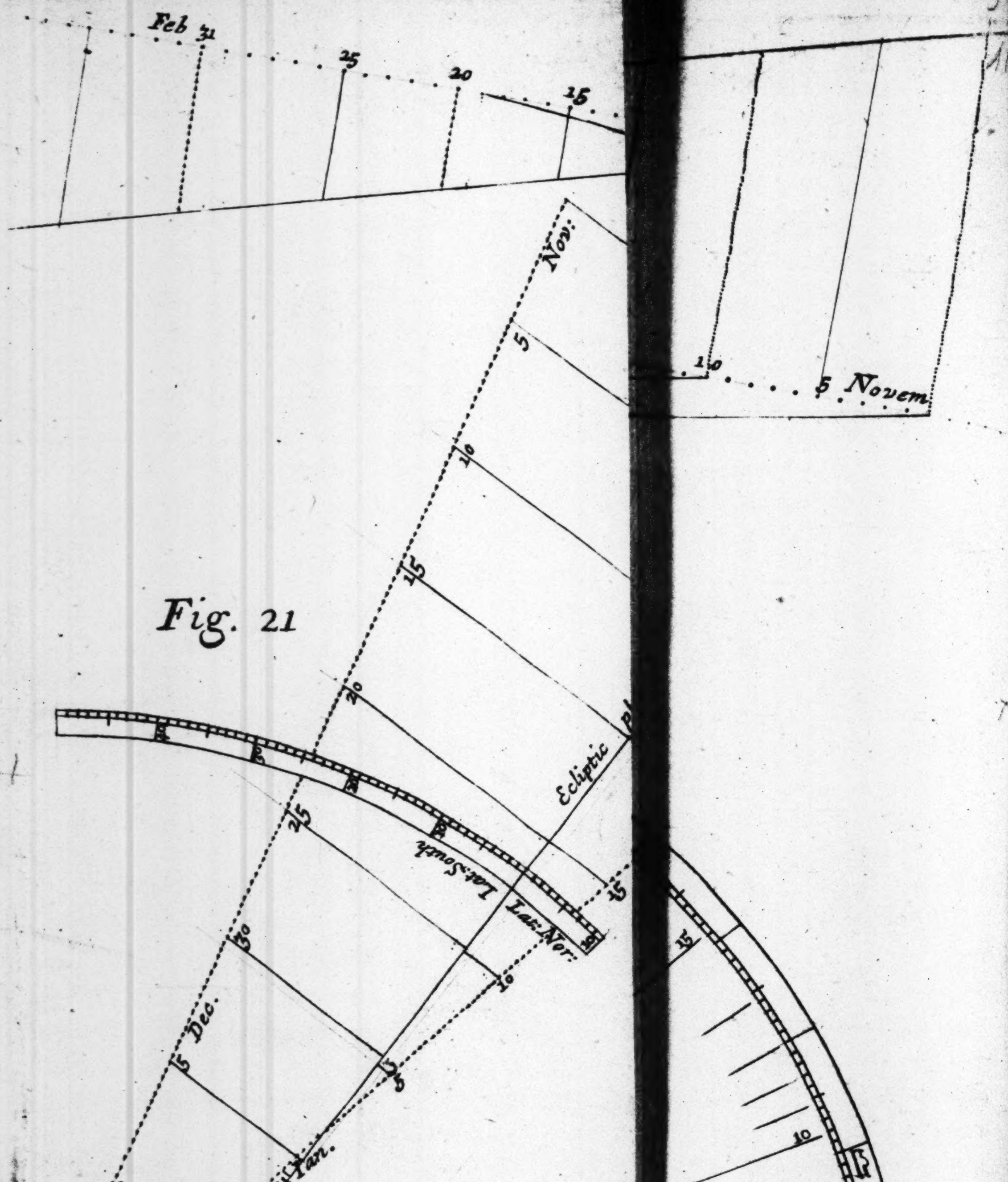

Fig. 21

AN ATTEMPT

To prove the Motion of the

EARTH

BY

OBSERVATIONS.

WHether the Earth move or ſtand ſtill hath been a Prob'em, that ſince *Copernicus* revived it, hath much exerciſed the Wits of our beſt modern Aſtronomers and Philoſophers, amongſt which notwithſtanding there hath not been any one who hath found out a certain manifeſtation either of the one or the other Doctrine. The more knowing and judicious have for many plauſible reaſons adhered to the *Copernican* Hypotheſis: But the generality of others, either out of ignorance or prejudice, have rejected it as a moſt extravagant opinion. To thoſe indeed who underſtand not the grounds and principles of Aſtronomy, the prejudice of common converſe

doth make it ſeem ſo abſurd, that a man ſhall as ſoon perſwade them that the Sun doth not ſhine, as that it doth not move; and as eaſily move the Earth as make them believe that it do's ſo already. For ſuch Perſons I cannot ſuppoſe that they ſhould underſtand the cogency of the Reaſons here preſented, drawn from the following obſervations of *Parallax*, much leſs therefore can I expect their belief and aſſent thereunto; to them I have only this to ſay, 'Tis not here my buſineſs to inſtruct them in the firſt principles of Aſtronomy, there being already Introductions enough for that purpoſe: But rather to furniſh the Learned with an *experimentum crucis* to determine between the *Tychonick* and *Copernican* Hypotheſes. That which hath hitherto continued the diſpute hath been the plauſibleneſs of ſome Arguments alledged by the one and the other party, with ſuch who have been by nature or education prejudiced to this or that way. For to one that hath been converſant only with illiterate perſons, or ſuch as underſtand not the principles of Aſtronomy and Geometry, and have had no true notion of the vaſtneſs of the Univerſe, and the exceeding minuteneſs of the Globe of the Earth in compariſon therewith, who have confined their imaginations & fancies only within the compaſs and pale of their own walk and proſpect, who can ſcarce imagine that the Earth is globous, but rather like ſome of old, imagine it to be a round plain covered with the Sky as with a Hemiſphere, and the Sun, Moon, and Stars to be holes through it by which the Light of Heaven comes down; that ſuppoſe themſelves in the center of this plain, and that the Sky doth touch that plain round the edges, ſupported in part by the Mountains; that ſuppoſe the Sun as big as a Sieve, and the Moon as a *Cheddar* Cheeſe, and hardly a mile off. That wonder why the Sun, Moon, and Stars do not fall down like Hail-ſtones; and that will be martyr'd rather then grant that there may be Antipodes, believing it abſolutely impoſſible, ſince they muſt neceſſarily fall down into the Abyſs below them: For how can they go with their feet towards ours, and their heads downwards, without making their brains addle. To one I ſay, thus prejudiced with theſe and a thouſand other fancies and opinions more ridiculous and abſurd to knowing men, who can ever imagine that the uniformity and harmony of the Celeſtial bodies and motions, ſhould be an Argument prevalent to perſwade that the Earth moves about the Sun: Whereas that Hypotheſis which ſhews how to

ſalve

ſalve the appearances by the reſt of the Earth and the motion of the Heavens, ſeems generally ſo plauſible that none of theſe can reſiſt it.

Now though it may be ſaid, 'Tis not only thoſe but great Geometricians, Aſtronomers and Philoſophers have alſo adhered to that ſide, yet generally the reaſon is the very ſame. For moſt of thoſe, when young, have been imbued with principles as groſs and rude as thoſe of the Vulgar, eſpecially as to the frame and fabrick of the World, which leave ſo deep an impreſſion upon the fancy, that they are not without great pain and trouble obliterated: Others, as a further confirmation in their childiſh opinion, have been inſtructed in the *Ptolomaick* or *Tichonick* Syſtem, and by the Authority of their Tutors, over-awed into a belief, if not a veneration thereof: Whence for the moſt part ſuch perſons will not indure to hear Arguments againſt it, and if they do, 'tis only to find Anſwers to confute them.

On the other ſide, ſome out of a contradicting nature to their Tutors; others, by as great a prejudice of inſtitution; and ſome few others upon better reaſoned grounds, from the proportion and harmony of the World, cannot but imbrace the *Copernican* Arguments, as demonſtrations that the Earth moves, and that the Sun and Stars ſtand ſtill.

I confeſs there is ſomewhat of reaſon on both ſides, but there is alſo ſomething of prejudice even on that ſide that ſeems the moſt rational. For by way of objection, what way of demonſtration have we that the frame and conſtitution of the World is ſo harmonious according to our notion of its harmony, as we ſuppoſe? Is there not a poſſibility that the things may be otherwiſe? nay, is there not ſomething of probability? may not the Sun move as *Ticho* ſuppoſes, and the Planets make their Revolutions about it whilſt the Earth ſtands ſtill, and by its magnetiſm attracts the Sun, and ſo keeps him moving about it, whilſt at the ſame time ☿ and ♀ move about the Sun, after the ſame manner as ♄ and ♃ move about the Sun whilſt the Satellites move about them? eſpecially ſince it is not demonſtrated without much art and difficulty, and taking many things for granted which are hard to be proved, that there is any body in the Univerſe more conſiderable then the Earth we tread on. Is there not much reaſon for the Hypotheſis of *Ticho* at leaſt, when he with all the accurateneſs that he arrived to with his vaſt Inſtru-

ments, or *Riccioli*, who pretends much to out-ſtrip him, were not able to find any ſenſible Parallax of the Earths Orb among the fixt Stars, eſpecially if the obſervations upon which they ground their aſſertions, were made to the accurateneſs of ſome few Seconds? What then, though we have a Chimera or Idea of perfection and harmony in that Hypotheſis we pitch upon, may there not be a much greater harmony and proportion in the conſtitution it ſelf which we know not, though it be quite differing from what we fancy? Probable Arguments might thus have been urged both on the one and the other ſide to the Worlds end; but there never was nor could have been any determination of the Controverſie, without ſome poſitive obſervation for determining whether there were a Parallax or no of the Orb of the Earth; This *Tycho* and *Riccioli* affirm in the Negative, that there is none at all: But I do affirm there is no one that can either prove that there is, or that there is not any Parallax of that Orb amongſt the fixt Stars from the Suppellex of obſervations yet made either by *Tycho*, *Riccioli*, or any other Writer that I have yet met with from the beginning of writing to this day. For all Obſervators having hitherto made uſe of the naked eye for determining the exact place of the object, and the eye being unable to diſtinguiſh any angle leſs then a minute, and an obſervation requiſite to determine this requiring a much greater exactneſs then to a minute, it doth neceſſarily follow that this *experimentum crucis* was not in their power, whatever either *Tycho* or *Riccioli* have ſaid to the contrary, and would thence overthrow the *Copernican* Syſtem, and eſtabliſh their own. We are not therefore wholly to acquieſs in their determination, ſince if we examine more nicely into the obſervations made by them, together with their Inſtruments and wayes of uſing them, we ſhall find that their performances thereby were far otherwiſe then what they would ſeem to make us believe. The Controverſie therefore notwithſtanding all that hath been ſaid either by the one or by the other Party, remains yet undetermined, Whether the Earth move above the Sun, or the Sun about the Earth; and all the Arguments alledged either on this or that ſide, are but probabilities at beſt, and admit not of a neceſſary and poſitive concluſion. Nor is there indeed any other means left for humane induſtry to determine it, ſave this one which I have endeavoured to make; and the unqueſtionable

certainty

certainty thereof is a moſt undenyable Argument of the truth of the *Copernican* Syſteme; and the want thereof hath been the principal Argument that hath hitherto ſomewhat detained me from declaring abſolutely for that Hypotheſis, for though it doth in every particular almoſt ſeem to ſolve the appearances more naturally and eaſily, and to afford an exceeding harmonious conſtitution of the great bodies of the World compared one with another, as to their magnitudes, motions, and diſtances, yet this objection was alwayes very plauſible to moſt men, that it is affirmed by ſuch as have written more particularly of this ſubject, that there never was any ſenſible Parallax diſcovered by the beſt obſervations of this ſuppoſed annual motion of the Earth about the Sun as its center, though moved in an Orb whoſe Diameter is by the greateſt number of Aſtronomers reckoned between 11 and 12 hundred Diameters of the Earth: Though ſoune others make it between 3 and 4 thouſand; others between 7 and 8; and others between 14 and 15 thouſands; and I am apt to believe it may be yet much more, each Diameter of the Earth being ſuppoſed to be between 7 and 8 thouſand Engliſh miles, and conſequently the whole being reduced into miles, if we reckon with the moſt, amounting to 120 millions of Engliſh miles. It cannot, I confeſs, but ſeem very uncouth and ſtrange to ſuch as have been uſed to confine the World with leſs dimenſions, that this annual Orb of the Earth of ſo vaſt a magnitude, ſhould have no ſenſible Parallax amongſt the fixt Stars, and therefore 'twas in vain to indeavour to anſwer that objection. For it is unreaſonable to expect that the fancies of moſt men ſhould be ſo far ſtreined beyond their narrow dimenſions, as to make them believe the extent of the Univerſe ſo immenſly great as they muſt have granted it to be, ſuppoſing no Parallax could have been found.

The Inquiſitive Jeſuit *Riccioli* has taken great pains by 77 Arguments to overthrow the *Copernican* Hypotheſis, and is therein ſo earneſt and zealous, that though otherwiſe a very learned man and good Aſtronomer, he ſeems to believe his own Arguments; but all his other 76 Arguments might have been ſpared as to moſt men, if upon making obſervations as I have done, he could have proved there had been no ſenſible Parallax this way diſcoverable, as I believe this one Diſcovery will anſwer them, and 77 more, if ſo many can be thought of and

produced

produced against it. Though yet I confeſs had I fail'd in diſcovering a Parallax this way, as to my own thoughts and perſwaſion, the almoſt infinite extenſion of the Univerſe had not to me ſeem'd altogether ſo great an abſurdity to be believed as the Generality do eſteem it; for ſince 'tis confeſſedly granted on all hands the diſtance of the fixt Stars is meerly hypothetical, and not founded on any other ground or reaſon but fancy and ſuppoſition, and that there never was hitherto any Parallax obſerved, nor any other conſiderable Argument to prove the diſtances ſuppoſed by ſuch as have been moſt curious and inquiſitive in that particular, I ſee no Argument drawn from the nature of the thing that can have any neceſſary force in it to determine that the ſaid diſtance cannot be more then this or that, whatever it be that is aſſigned. For the ſame God that did make this World that we would thus limit and bound, could as eaſily make it millions of millions of times bigger, as of that quantity we imagine; and all the other appearances except this of Parallax would be the very ſame that now they are. To me indeed the Univerſe ſeems to be vaſtly bigger then 'tis hitherto aſſerted by any Writer, when I conſider the many differing magnitudes of the fixt Stars, and the continual increaſe of their number according as they are looked after with better and longer Teleſcopes. And could we certainly determine and meaſure their Diameters, and diſtinguiſh what part of their appearing magnitude were to be attributed to their bulk, and what to their brightneſs, I am apt to believe we ſhould make another diſtribution of their magnitudes, then what is already made by *Ptolomy*, *Tycho*, *Kepler*, *Bayer*, *Clavius*, *Grienbergerus*, *Piſſ*, *Hevelius* and others.

For ſuppoſing all the fixt Stars as ſo many Suns, and each of them to have a Sphere of activity or expanſion proportionate to their ſolidity and activity, and a bigger and brighter bodied Star to have a proportionate bigger ſpace or expanſion belonging to it, we ſhould from the knowledge of their Diameters and brightneſſes be better able to judge of their diſtances, and conſequently aſſign divers of them other magnitudes then thoſe already ſtated: Eſpecially ſince we now find by obſervations, that of thoſe which are accounted ſingle Stars, divers prove a congeries of many Stars, though from their near appearing to each other, the naked

ked eye cannot distinguish them; Such as those Stars which are called *Nebulous*, and those in *Orion* Sword, and that in the head of *Aries*, and a multitude of others the Telescope doth now detect. And possibly we may find that those twenty magnitudes of Stars now discovered by a fifteen foot Glass, may be found to increase the magnitude of the Semidiameter of the visible World, fourty times bigger then the *Copernicans* now suppose it between the Sun and the fixt Stars, and consequently sixty four thousand times in bulk. And if a Telescope of double or treble the goodness of one of fifteen should discover double or treble the said number of magnitudes, would it not be an Argument of doubling or trebling the former Diameter, and of increasing the bulk eight or twenty seven times. Especially if their apparent Diameters shall be found reciprocal to their Distances (for the determination of which I did make some observations, and design to compleat with what speed I am able.) But to digress no further, This grand objection of the *Anticopernicans*, which to most men seem'd so plausible, that it was in vain to oppose it, though, I say, it kept me from declaring absolutely for the *Copernican* Hypothesis, yet I never found any absurdity or impossibility that followed thereupon: And I alwayes suspected that though some great Astronomers had asserted that there was no Parallax to be found by their observations, though made with great accurateness, there might yet be a possibility that they might be mistaken; which made me alwayes look upon it as an inquiry well worth examining: first, Whether the wayes they had already attempted were not subject and lyable to great errors and uncertainties: and secondly, Whether there might not be some other wayes found out which should be free from all the exceptions the former were incumbred with, and be so far advanced beyond the former in certainty and accurateness, as that from the diligent and curious use thereof, not only all the objections against the former might be removed, but all other whatsoever that were material to prove the ineffectualness thereof for this purpose.

I began therefore first to examine into the matter as it had already been performed by those who had asserted no sensible Parallax of the annual Orb of the Earth, and quickly found that (whatever they asserted) they could never determine whether

there

there were any or no Parallax of this annual Orb; especially if it were less then a minute, which *Kepler* and *Riccioli* hypothetically affirm it to be: The former making it about twenty four Seconds, and the latter about ten. For though *Tycho*, a man of unquestionable truth in his assertions, affirm it possible to observe with large Instruments, conveniently mounted and furnished with sights contrived by himself (and now the common ones for Astronomical Instruments) to the accurateness of ten Seconds; and though *Riccioli* and his ingenious and accurate Companion *Grimaldi* affirm it possible to make observations by their way, with the naked edge to the accurateness of five Seconds; Yet *Kepler* did affirm, and that justly, that 'twas impossible to be sure to a less Angle then 12 Seconds: And I from my own experience do find it exceeding difficult by any of the common sights yet used to be sure to a minute. I quickly concluded therefore that all their endeavours must have hitherto been ineffectual to this purpose, and that they had not been less imposed on themselves, then they had deceived others by their mistaken observations. And this mistake I found proceeded from divers inconveniencies their wayes of observations were lyable to. As first from the shrinking and stretching of the materials wherewith their Instruments were made, I conceive a much greater angle then that of a minute may be mistaken in taking an altitude of fifty Degrees. For if the Instruments be made of Wood, 'tis manifest that moyst weather will make the frame stretch, and dry weather will make it shrink a much greater quantity then to vary a minute: and if it be Metal, unless it be provided for in the fabrick of the Instrument accordingly, the heat of Summer, when the Summer observations are to be made, will make the Quadrant swell, and the cold of Winter will make it shrink much more then to vary a minute: Both which inconveniencies ought to be removed. Next the bending and warping of an Instrument by its own weight, will make a very considerable alteration. And thirdly, the common way of Division is also lyable to many inconveniencies: And 'tis hardly possible to ascertain all the subdivisions of Degrees into minutes for the whole Quadrant, though that be not altogether impossible. But I will suppose that they did foresee, and in some manner prevent all these inconveniencies, especially *Tycho* and *Riccioli*, who seem to have been aware thereof. But there was

one

one inconvenience which was worſe then all the reſt, which they ſeem not to have been ſufficiently ſenſible of, from whence proceeded all their own miſtakes, and their impoſing upon others, and that was from their opinion that the ſight of the naked eye was able to diſtinguiſh the parts of the object as minutely as the limb of the Quadrant (of what largeneſs ſoever) was capable of Diviſions; whereas 'tis hardly poſſible for any unarmed eye well to diſtinguiſh any Angle much ſmaller then that of a minute: and where two objects are not farther diſtant then a minute, if they are bright objects, they coaleſs and appear one, though I confeſs, if they be dark objects, and a light be interpoſed, the diſtance between them ſhall be viſible, though really much leſs then a Second; and yet notwithſtanding, my firſt aſſertion ſtands good; for though a bright object, as a candle or light at a diſtance, or a Star, or the like, can be ſeen by the eye, though its body do really not ſubtend an Angle of one third, yet it proceeds from a radiation (that is, from reflection and refraction together) in the air and in the eye, whereby the body thereof is repreſented to the naked eye ſome hundred times bigger then it really is. That this is ſo, any one that will but carefully examine will find it true.

It was, I doubt not, their extraordinary deſire and care to be exact, that cauſed them to make their Inſtruments ſo large, and to ſubdivide them to ſuch an exactneſs, as to diſtinguiſh, if poſſible, to Seconds; And I queſtion not but that they uſed their utmoſt indeavour in directing the ſight to the object: but ſince the naked eye cannot diſtinguiſh an Angle much ſmaller then a minute, and very few to a whole minute, all their charge and trouble in making and managing large Inſtruments, and in calculating and deducing from them, was as to this uſe in vain. Hence I judged that whatever mens eyes were in the younger age of the World, our eyes in this old age of it needed Spectacles; and therefore I reſolved to aſſiſt my eyes with a very large and good Teleſcope, inſtead of the common ſights, whereby I can with eaſe diſtinguiſh the parts of an object to Seconds: and I queſtion not but that this way may be yet made capable of diſtinguiſhing much more curiouſly, poſſibly even to ſome few Thirds. This invention removed that grand inconvenience which all former obſervations were ſpoiled with: but there re-

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mained yet further this difficulty, How to make an Instrument large enough for this purpose, that I might be assured did not shrink, nor warp, nor stretch so much as to vary a Second; for such is the nature of all Materials that can be made use of for Instruments of the bigness I designed this, that 'tis almost impossible to make a moveable Instrument that shall not be subject to a variation of divers Seconds: It was therefore my next inquiry where I might fix this Archimedean Engine that was to move the Earth. For the doing of which, I knew 'twas in vain to consult with any Writer or Astronomer, having never then heard of any person that had ever before that time had any thoughts thereof: and when I first propounded it to the *Royal Society*, 'twas look'd upon as a new thought, and somewhat extravagant, and hardly practicable, until upon hearing my explication, and the various wayes how it might be reduced into practise, it was at length judged possible, and desirable to be tryed. I propounded therefore to them the several ways that it was possible to be performed, and what method was to be observed in every one of them, and somewhat of the conveniencies and inconveniencies in each of them; for having seriously meditated upon the Inquiry, I quickly thought of many expedients for the doing thereof. As first, I had thoughts of making use of some very great and massy Tower or Wall that were well setled, or of some large Rock or Hill whereunto I might fix my Glasses, so as to take the exact altitude of some eminent Star near the Pole of the Ecliptik, when at its greatest height, at two differing times of the year; to wit, about the Summer and Winter Solstice, to see if possibly I could discover any difference of altitude between the first and second observation. But to accomplish this (besides the vast difficulty there would have been to have measured such an Angle to the accurateness requisite, if at least it were desired to have the Angle of altitude to Minutes and Seconds, which ought also to have been repeated as oft as any observation had been made for fear of setling or swelling, &c.) I was destitute of such a convenience near my habitation; besides, had I had my wish, I found that 'twas lyable to an inconvenience that would wholly overthrow my whole design, which I knew not well how to avoid: Namely, to that which hath hitherto made even the very best

beſt obſervations of Parallaxes ineffectual and uncertain, the *refraction of the Air* or *Atmoſphere*, which though it could have been but very little at the greateſt altitude of the Pole of the Ecliptick, yet it might have been enough plauſibly to have ſpoiled the whole obſervation, and to have given the *Anticopernicans* an opportunity of evading the Arguments taken from it, eſpecially upon the account of the differing conſtitution of the Atmoſphere in *June* and *December*, which might have cauſed ſo much a greater refraction of the ſame altitude at one time then another, as would have been ſufficient to have made this obſervation ineffectual for what it was deſigned. Adde to this, that it would have been no eaſie matter to have ſet the Glaſſes or Teleſcope exactly againſt the Meridian, ſo as to ſee the higheſt altitude of any Star near the Pole of the Ecliptick diſtinctly to a Second.

The like difficulties I found if obſervations were made of the greateſt altitude of the Pole of the Ecliptick in *June* and *December*, or the leaſt altitude of the ſame in *December* and *June*. For beſides all the uncertainties that the Inſtruments, be they what they will, are liable to, the grand inconvenience of the refraction of the Air, which is enough to ſpoil all obſervations if it be intermixed with uncertainty, in the former is conſiderable, and in the later intolerable.

Having therefore examined the wayes and Inſtruments for all manner of Aſtronomical obſervations hitherto made uſe of, and conſidered of the inconveniencies and imperfections of them; and having alſo duly weighed the great accurateneſs and certainty that this obſervation neceſſarily required: I did next contrive a way of making obſervations that might be free from all the former inconveniencies and exceptions, and as near as might be, fortified againſt any other that could be invented or raiſed againſt it. This way then was to obſerve by the paſſing of ſome conſiderable Star near the Zenith of *Greſham Colledge*, whether it did not at one time of the year paſs nearer to it, and at another further from it: for if the Earth did move in an Orb about the Sun, and that this Orb had any ſenſible Parallax amongſt the fixt Stars; this muſt neceſſarily happen, eſpecially to thoſe fixt Stars which were neareſt the Pole of the Ecliptick. And that this is ſo, any one may plainly perceive if he

conſider the annexed Scheme, *Fig.* I. where let S repreſent the Sun placed as it were in the center of the Planetary Orbs, A B C D an imaginary Orb of the fixt Stars of the firſt magnitude, whoſe center for demonſtration ſake we will ſuppoſe the Sun. Let ♈♋♎♑ repreſent the Orb in which the Earth is ſuppoſed to move about the Sun, obliquely projected on the Paper. Let ♑ repreſent the Earth in *Capricorn*, and ♋ the Earth in *Cancer*, let 1 2. 1 2. repreſent the imaginary Axis of the Earth, keeping continually a paralleliſm to its ſelf, and let ♑ A D C D ♋ repreſent an imaginary Plain paſſing through the center of the Star at D in the Solſtitial Colure, and the two centers of the Earth in ♑ and ♋, and C repreſent the Zenith point of *Greſham Colledge* at noon, when the Earth is in *Cancer*, and A the Zenith point of the ſaid *Colledge* at midnight in the aforeſaid Orb A B C D when the Earth is in *Capricorn*, 'tis manifeſt therefore that ſince the Poles of the Earth, the Poles of the Ecliptick, and the Zenith points of the Earth at noon, when in *Cancer*, and at midnight, when in *Capricorn*, are all in the ſame Plain; and that the Axis of the Earth keeps alwayes its paralleliſm, and that the Angles made by the Perpendiculars of *Greſham Colledge*, with the Axes are alwayes the ſame, that the aforeſaid Perpendiculars of the ſaid *Colledge* ſhall be parallel alſo one to another, and conſequently denote out two points in the aboveſaid Orb A and C as far diſtant from each other as the parallel Lines A ♑ and C ♋ are, and conſequently the point A ſhall be farther from the Star in D, and the point C ſhall be nearer to it, when in the Meridian near the Zenith of *London*, and conſequently if the ſaid Star be obſerved when in the Meridian of the place aboveſaid, if there be any ſuch difference conſiderable, it may be found if convenient Inſtruments and care be made uſe of for the obſervation thereof: and the difference between the Angle A ♑ D, and the Angle C ♋ D, will give the parallactical Angle ♑ D ♋ of the Orb of the Earth to the fixt Star D of the firſt magnitude. The ſame demonſtration will hold *mutatis mutandis*, ſuppoſing the Star be not in the Meridian or Plain aboveſaid, but in ſome other Meridian, as any one upon well conſidering the nature of the thing it ſelf may eaſily prove, if the obſervation be made when the Zenith paſſes by the Star at midnight, and at mid-

mid-day. But the nearer the Zenith of the place of obſervation paſſeth to the Pole point of the Ecliptick, the better: The Angle of Parallax being ſtill the more ſenſible. Therefore the beſt place to compleat this obſervation were in ſome place under the Polar Circles, as in *Iſeland*, where the Zenith of the place at the times aboveſaid, muſt conſequently paſs at one time to the North ſide of the Pole of the Ecliptick, and at the other on the South ſide, and the Zenith of *March* and *Sept.* muſt paſs through the very Pole-point it ſelf. Now it falling out ſo, that there is no conſiderable Star in that part of the Heavens nearer the above ſaid Plain, and nearer the Zenith point of *Greſham Colledge* in that Plain, then the Bright Star in the head of the *Dragon*, I made choice of that Star for the object by which I deſigned to make this obſervation, finding the Zenith point of *Greſham Colledge* to paſs within ſome very few minutes of the Star it ſelf; the declination thereof according to *Riccioli* being 51°. 36'. 7". and the Plain the Star and Pole of the World, making an Angle with the aforeſaid Plain but of 2°. 52. 36, the right aſcention thereof being according to *Riccioli* 267°. 7'. 24".

And that this may be made a little plainer, let us ſuppoſe in the third *Figure*, the North part of the Heavens projected ſtereographical upon a Plain to which the Axis is perpendicular. Let p repreſent the Pole, e the Pole of the Ecliptick, l the bright Star in the head of *Draco*, and let a c c c repreſent an imaginary Circle deſcribed by the Zenith of *Greſham Colledge* among the fixt Stars in *June*, and b d d d a like Circle deſcribed by the ſaid Zenith in *December*, and e f f f a like Circle deſcribed as above in *March*, and g h h h in *September*. It is very evident that the true diſtances of the Zeniths in that part of the Meridian which is next the Pole of the Ecliptick, to wit, in the head of the Conſtellation *Draco*, ſhall be to the true diſtances of the ſaid Zeniths in that part which is furtheſt from the ſaid Pole, to wit, near the conſtellation of *Auriga in conſequentia*, as the ſign of 75 degrees to the ſign of 14°. 54', and the variation of the Zeniths, or the Angle of Parallax here at *Greſham Colledge*, to the Angle of Parallax in *Iſeland*, or any other place under the Pole of the Ecliptick, or Artick Circle is, as the ſign of ſeventy five to the ſign of ninety or the *Radius*.

m. This will be very evident if we consider in the second Scheme; AB to represent the Diameter of the great Orb: AC and BD the perpendiculars of *Iseland*, or some other place under the Polar Circle, GA, HB the perpendiculars of *Gresham Colledge* in *Draco*: and LA, MB the perpendiculars of the same place to the Solstitial Colure near *Auriga*, the several distances CD, GH, IK, LM, will be as the signs of 90°|75°|66°.30'|14°.54'|. to wit, as the Lines or Cords A B. A O. P B. Q B.

I might have made observations of the distances of the transits of our Zenith from any other Star as well as from this of *Draco*, and the same Phenomena might have been observed, taking care to make one of the observations when the Star is in the Zenith at midnight, and the other when the same Star is in the Zenith at noon or mid-day; and upon this account when I next observe, I design to observe the transits of our Zenith by *Benenaim*, or the *ultima caudæ ursæ majoris*, it being a Star of the second magnitude, and having almost as much declination as *Gresham Colledge* hath latitude. The principal dayes of doing which will be about the 4 of *April*, when our Zenith passeth by the said Star at midnight, and the 7 of *October*, when it passeth by it at noon or mid-day: the reason of all which will be sufficiently manifest to any one that shall well consider the preceeding explanation.

This Star I would the rather observe, because as it is placed so as that the Parallax thereof will be almost as great as of the Pole of the Ecliptick in *Iseland*, or under the Artick Circle, so it being a Star of the second magnitude, and consequently perhaps as near again as one of the fourth, the Angle of Parallax will be near about twice as big, and the Star it self much more easie to be seen in the day time. This will be very easie to be understood, if we consider in the first Scheme the differing distances of the Orb *A B C D*, in which we may suppose the Stars of the second magnitude to be fixt, and of the Orb α β γ δ, in which we may suppose the Stars of the fourth magnitude, and a b c d in which we may suppose those of the third magnitude, and A B C D in which we may suppose those of the first; for if the Stars are further and further removed from the Sun, according as they appear less and less to us, the parallactical difference found by observation must necessarily

be

be leſs and leſs, according as the obſervation is made of leſs and leſs Stars.

The reaſons then why I made choice of this way of obſerving will be eaſie to any one that ſhall conſider that hereby, firſt, I avoid that grand inconvenience wherewith all ancient and modern obſervations have been perplext, and as to Parallax inſignificant, and that is the refraction of the Air or Atmoſphere. How great an inconvenience that was is obvious, ſince 'tis certainly much greater at one time then another, and never at any certainty; and ſecondly, 'Tis not equally proportionable, for ſometimes the refraction is greater at ſome diſtance above the Horizon, then in or nearer to the Horizon it ſelf, and ſometimes the quite contrary, which I have very often obſerved; and this to ſo exorbitant a difference, as to confound all Hypothetical Calculations of Tables for this purpoſe. This ariſeth from the uncertain and ſudden variations of the Air or Atmoſphere, either from heat and cold, from the thickneſs and thinneſs of Vapours, from the differing gravity and levity, from the winds, currents, and eddyes thereof, all which being not ſo well underſtood by what way, and in what degree, and at what time they work and operate upon the Air, muſt needs make the refraction thereof exceedingly perplext, and the reduction thereof to any certain theory fit for practice, a thing almoſt impoſſible. Now if we are uncertain what part of the obſerved Angle is to be aſcribed to refraction, we are uncertain of the whole obſervation as far as the poſſible uncertainty of refraction. Let me have but the liberty of ſuppoſing the refraction what I pleaſe, and of fixing the proportional decreaſe thereof according to the various elevation of the Rayes above the Horizon; I will with eaſe make out all the viſible Phenomena of the Univerſe, Sun, Moon, and Stars, and yet not ſuppoſe them above a Diameter of the Earth diſtant. Now in this obſervation there is no refraction at all, and conſequently be the Air thicker or thinner, heavier or lighter, hotter or colder, be it in Summer or Winter, in the night or the day, the ray continually paſſeth directly, and is not at all refracted and deflected from its ſtreight paſſage. In the next place, by this way of obſerving I avoid all the difficulties that attend the making, mounting, and managing of great Inſtruments: For I

have

have no need of Quadrant, Sextant, or Octant, nor of any other part of Circle bigger then a Degree at moſt; nor have I need to take care of the diviſions and ſubdiviſions thereof, nor of the ſubſtance whether made of Iron, Braſs, Copper, or Wood, nor whether the parts thereof ſhrink or ſwell, or bend or warp, to all which the beſt Inſtruments hitherto made uſe of, have been ſome wayes or other lyable. And notwithſtanding the vaſt care and expence of the noble *Ticho* about the making, fixing, and uſing his great Inſtruments; yet I do not find them ſo well ſecured from divers of theſe inconveniences, but that they were ſtill ſubject to ſome conſiderable irregularities. Nay, notwithſtanding the ſeemingly much greater curioſity and expenſe of *Hevelius*, and his infinite labour and diligence in the compleating and uſing of his vaſt Apparatus of Aſtronomical Inſtruments, I do not find them ſo well ſecured, but that ſome of the cauſes of errors that I have before mentioned, may have had a conſiderable effect upon them alſo; eſpecially if they were ſuppoſed to meaſure an Angle to ſome few Seconds, as I ſhall hereafter perhaps have more occaſion to manifeſt. Now, if the Inſtruments of *Ticho* and *Hevelius*, (who had certainly two of the moſt curious and magnificent Collections of Aſtronomical Inſtruments that were ever yet got together or made uſe of) were ſubject to theſe uncertainties, What ſhall we ſay of all that other farrage of trumpery that hath been made uſe of by moſt others? We ſee therefore the neceſſity of the conjunction of Phyſical and Philoſophical with Mechanical and Experimental Knowledge, how lame and imperfect the ſtudy of Art doth often prove without the conjunction of the ſtudy of Nature, and upon what rational grounds it was that Sir *John Cutler*, the Patron and Founder of this Lecture, proceeded in joyning the contemplation of them both together.

The next thing was the Inſtrument for the making of this obſervation, ſuch a one as ſhould not be lyable to any of the former exceptions, nor any other new ones that were conſiderable. To this purpoſe I pitched upon a Teleſcope, the largeſt I could get and make uſe of, which I deſigned ſo to fix upright, as that looking directly upwards, I could be able certainly to obſerve the tranſits of any Stars over or near

the

the Zenith, and furniſhing it with perpendiculars and a convenient dividing Inſtrument, I ſhould be able not only to know exactly when the Star came to croſs the Meridian, but alſo how far it croſſed it from the Center or Zenith point of *Greſham Colledge*, either towards the North, or towards the South. All which Particulars, how I performed, I ſhall now in order deſcribe, and this ſomewhat the more diſtinctly, that ſuch as have a deſire to do the like, may be the more ready and better inabled to proceed with the ſame.

Firſt then (finding a Tube would be very troubleſome to the Rooms through which it paſt, eſpecially if it were placed pretty far in the Room, and that one wanted ſo free an acceſs as was neceſſary if it were planted nigh the wall, and that there was no abſolute neceſſity of ſuch an intermediate Tube, ſuppoſing there were a cell to direct the eye fixt to the Eye Glaſs, and that there were ſome ſhort cell to carry the Object Glaſs in at the top, ſo as to keep it ſteady, when raiſed upward or let downwards, the light in the intermediate Rooms not at all hindring, but rather proving of good uſe to this purpoſe for ſeeing the Menſurator) I opened a paſſage of about a foot ſquare through the roof of my lodgings (ſee the Fourth *Figure*) and therein fixt a Tube a a perpendicular and upright, of about ten or twelve foot in length, and a foot ſquare, ſo as that the lower end thereof came through the Ceiling, and was open into the Chamber underneath: This Tube I covered with a lid at the top q, houſed ſo as to throw off the rain, and ſo contrived, as I could eaſily open or ſhut it by a ſmall ſtring n o p, which came down through the Tube to the place where I obſerved. Within this perpendicular Tube a a, I made another ſmall ſquare Tube b b, fit ſo as to ſlide upwards and downwards, as there was occaſion, and by the help of a skrew to be fixt in any place that was neceſſary: Within this Tube in a convenient cell c, was fixt the Object Glaſs of the Teleſcope (that which I made uſe of was thirty ſix foot in length, having none longer by me, but one of ſixty foot, and ſo too long to be made uſe of in my Rooms) the manner of fixing which was this: The Glaſs it ſelf was fixed into a cell or frame of Braſs, ſo exactly fitted to it, that it went in ſtiff; and to fill up all the Interſtitia's, there was melted in hard Cement; this cell had a

ſmall barr that croſſed under the center of the Glaſs, or the aperture thereof; in which barr were drill'd two ſmall holes at equal diſtance from the middle of the Glaſs, through which the upper ends of the two perpendiculars d d were faſtned; and in the fixing this braſs cell or frame into the ſquare Tube that was to ſlide up and down, care was taken to make the barr lye as exactly North and South as could be, though that were not altogether ſo abſolutely neceſſary to this obſervation. Theſe perpendiculars d d faſtned to the barr hung 36 foot and better in length, and had at the lower ends of them two balls of lead e e as big as the Silks could bear, by which the loweſt parts of this Inſtrument were adjuſted, as I ſhall by and by explain. But firſt, I muſt acquaint the Reader, that I opened a ſo perpendicularly under this Tube a hole r r a foot ſquare in the floor below, which with ſhutters could be cloſed or opened upon occaſion; by this means I had a perpendicular Well-hole of about forty foot long, from the top of a to the lower floor s s. Upon the ſecond floor s s I fixed the frame that carried the Eye-glaſs and the other Apparatus fit to make this obſervation. I made then a Stool or Table, ſuch as is deſcribed in the ſame Fourth *Figure* i h h i, having a hole through the top or cover thereof h h, of about nine inches over; the middle of which I placed as near as I could perpendicularly under the middle of the Object Glaſs in the cell above, and then nailed the frame faſt to the floor by the brackets i i, that it could not ſtir; underneath the cover of this Table I made a ſlider g g, in which was fixed in a cell an eye Glaſs f, ſo as that I could through the eye Glaſs moved to and fro, ſee any part of the hole in the Table that I deſired, without ſtirring the ſtool from its fixtneſs. This was neceſſary, becauſe many Stars which were forerunners of this Star in *Draco*, and ſerved as warning to prepare for the approaching Star, went pretty wide from the parallel that paſſed over our Zenith; by this means alſo I took notice of the Star it ſelf, at above half a degree diſtance from the Zenith to the Eaſt, and ſo followed the motion of it with my eye Glaſs, and alſo with my meaſuring Clew, and at the ſame time told the Seconds beat by a Pendulum Clock, and ſo was very well prepared to take notice of all things neceſſary to compleat the obſervation, but might have been otherwiſe ſurpriſed

priſed by the ſuddain approach and ſwift motion of the ſaid Star. The meaſuring Inſtrument or Menſurator was a round thin plate or circle of Braſs, delineated in the Seventh *Figure*, the aperture a b of which was about nine inches over, croſſed in the middle by two very ſmall hairs a b and c d, which ſerved to ſhew the Zenith point at e, by which the Star was to paſs; there were alſo two other ſmall hairs f g and i h drawn parallel to that which was to repreſent the Eaſt and Weſt line, that paſt under our Zenith, theſe cut the Clue that repreſented the Meridian, or North and South Line at the places k and l, where the perpendicular points were made by the two long plumb lines: This Inſtrument was produced on the ſide a to n, n e being made fifteen times the length of e m, ſo that e m being one inch and two thirds, e n was twenty five inches: at n the line n e was croſt by a rule of about $3\frac{1}{2}$ foot long o p, which from the point n was divided each way into inches and parts, each inch being ſubdivided into thirty parts, which ſerved to determine, though not preciſely, the Seconds on the line c d, for a minute of a degree to a thirty ſix foot Glaſs, being very near one eighth part of an inch, and this eighth part, by the help of the Diagonal, being extended to two whole inches upon the three foot Rule o p, it became very eaſie to divide a part of c d, which ſubtended a minute into ſixty parts, and conſequently to ſubdivide it into Seconds. Now though the ſixtieth part of an eighth of an inch be very hardly diſtinguiſhable by the naked eye, yet by the help of looking through the Eye-glaſs placed in the cell, and ſo magnifying the Objects at the Menſurator more then ſixteen times, 'tis eaſie enough to diſtinguiſh it. But to proceed, I had one ſmall arm m t in the Menſurator, to which the Diagonal thred was faſtned at the point m, which ſerved for the more nice ſubdiviſions into Seconds; The other Diagonal thred which was faſtned at u, ſerved for ſuch obſervations where ſo great niceneſs was not ſo neceſſary, diſtinguiſhing only every four Seconds. The points where theſe Diagonal threds were faſtned, were exactly over the line a b, and the diſtances e m and e u were an inch and two thirds, and five inches.

There is ſomewhat of niceneſs requiſite to the fixing theſe Diagonal threads (which is very material) at m and u, and that

is that there be a ſmall ſpringing ſlit to pinch the hair faſt exactly over the line a b, ſo that the point of its motion may be preciſely in the ſaid Eaſt and Weſt line, and not ſometimes in it, and ſometimes out of it, which it is apt to be, if the Diagonal line be fixt in a hole, and move round in it.

This was the Menſurator by which I meaſured the exact diſtance of the Stars from our Zenith: it may be alſo made uſe of for the meaſuring the Diameters of the Planets; for the examining the exact diſtances of them from any near approaching fixt Stars; for meaſuring the diſtances of the Satellites of *Jupiter* and *Saturn* from their diſcks, for taking the diameters and magnitudes of the ſpots of the Moon, and for taking the diſtances of approaching Stars, and for many other menſurations made by Teleſcopes or Microſcopes, if it be ſo placed as to be in the focus of the Object Glaſs and Eye Glaſs. I could here deſcribe at leaſt thirty other ſorts, ſome by the help of ſcrews, others by the help of wedges, ſome after the way of proportional Compaſſes, others by wheels, others by the way of the Leaver, others by the way of Pullies, and the like; any one of which is accurate enough to divide an inch into 100, 1000, 10000 parts if it be neceſſary; but I muſt here omit them, they being more proper in another place, and ſhall only name one other, becauſe I ſometimes made uſe of it in this obſervation, which is as ſimple and plain as this I have deſcribed, and altogether as accurate; but for ſome accidental circumſtances in the place where I made my obſervation, was not altogether ſo convenient as the former. This Menſurator then is made thus: take a Rule of what length it ſeems moſt convenient for the preſent occaſion, as two, three, or four foot long, repreſented by a b in the Eighth *Figure*, divide this into 100, 1000, 10000 equal parts, with what accurateneſs 'tis poſſible, between the points a b. On the top of this Rule, at each end fix two croſs pieces g h and e f, then from the two croſs pieces e f and g h, ſtrain two very fine and even clues, as Silkworms clues, curious ſmall hairs, or the like, ſo as that they croſs each other at n, and be diſtant at o and p, an inch, or any other certain meaſure deſired. Let this Rule, bezelled on each ſide, ſlip in a frame between two cheeks q and r, upon the top of which ſtrein another ſmall hair as s t. This frame muſt be faſtned to the Teleſcope,

leſcope, ſo as s t may lye in a due poſition to the Eye Glaſs of it. Now in the time of obſervation the frame q r being faſtned to the Teleſcope as above, by ſliding the Rule a b to and fro, you give upon the line s t any length deſired, which is noted out by the line s t upon the rule; for if o p be put one inch, then x y will be $\frac{424}{1000}$ of an inch, and if o p be the ſubtenſe of 10 minutes, then x y will be the ſubtenſe of $4\frac{24}{24}$; this is ſo plain, ſimple, and eaſie, that as any ordinary Workman will be able to make it, ſo I doubt not but every Reader will, without more application, underſtand both the deſcription and uſe thereof. I ſhall return therefore to the deſcription of the former Menſurator.

The next thing then is the way of fixing this Menſurator, ſo as to ſet the threads in their due poſture, that is Eaſt and Weſt, and North and South, and that they cut each other under the middle of the Glaſs. This laſt was that which had the moſt of difficulty in the whole Experiment. For the performing of this, I removed the ſlider underneath the Table that carried the Eye Glaſs, and alſo the Menſurator, and ſuffered the plumb lines to hang down through the aperture of the Table, and that the Balls might come the ſooner to their perpendicularity, I ſuffered them to hang into a veſſel of water, deep and wide enough, that they might not touch either ſide or bottom.

This expedient of hanging the plumbets in water I mention, becauſe without it 'tis not to be imagined how much time is loſt by expectation of the ſettlement of the ſaid perpendiculars, and how very apt they are to be made to vibrate by the little imperceptible motion of the Air, and by any ſmall hair or other impediment how apt to be put out of their perpendicularity: which by the way makes me very fearful that all common Inſtruments have hitherto been lyable to very great errors, by the unaccurate hanging of their plumb lines, being made for the moſt part to hang and play againſt the ſide of the Inſtrument. By this means they would ſoon come to hang perpendicularly, and be ſo detained when in that poſture; not being apt to be ſtirred by the motion of the Air, or their own ſwings; and whilſt thus ſteady, I fixed two ſmall arms of Braſs, ſuch as are deſcribed in the Seventh Figure by z z, z z, which had ſmall holes at the extreams, with a ſmall ſlit on the ſide to admit

admit or emit the plumb line as there was occasion; one of these is more at large described in the Sixth *Figure*. Now the plumb line being let into the middle of this, I did with all the accurateness I could so fix the said arm, that the plumb line past exactly through the middle of the hole y. When I was sufficiently satisfied that the plumb line past exactly through the middle of the trying arms, I fixed those arms z z, z z, and removed the plumb lines, then I laid the Mensurator l l in the Fourth *Figure*, upon the surface of the Table, and took great care that the crosses k and l in the Seventh *Figure*, lay exactly under the middle of the holes in the arms, which having done by the help of certain screws, I fixt the Mensurator fast to the Table, and prepared for the observations, putting in the slider g g in the Fourth *Figure*, that carried the cell f, and lying down upon a Couch (k of the Fourth *Figure*) made purposely for this observation, I could look directly upward, and with my left hand move the Cell and Eye Glass so as to find any Star which passed within the hole of the Table, and at the same time with my right hand I could move the Diagonal thread (r m of the Seventh *Figure*) so as to find exactly how far distant from the Zenith e, either Northwards or Southwards, the Stars past the Meridian d c, and giving notice to my Assistant to prepare, he upon the sign given took notice exactly by a Pendulum Clock to the parts of a Second when the said Stars past, and also took notice what division the Diagonal thread m r cut upon the Rule o p.

With all these difficulties I was forced to adjust the Instrument every observation I made, both before and after it was made, which hath often made me wish that I were near some great and solid Tower, or some great Rock or deep well, that so I might fix all things at once, and not be troubled continually thus to adjust the parts of the said Instrument; for whoever hath that opportunity will, I question not, especially if the lines of his Mensurator be made of the single clues of a Silkworm, with much ease discover plainly a change of the distance of Stars of the greater magnitude from the Zenith, in a much shorter time then six moneths. This variation also will be much more easie to be discovered, if instead of a thirty six foot Glass, there be made use of one of four times that length,

length, to wit, one of one hundred fourty four foot; and if inſtead of a Tower ſome deep and dry Well be made uſe of, ſuch as I have ſeen at a Gentlemans houſe not far from *Banſted Downs* in *Surry*, which is dugg through a body of chalk, and is near three hundred and ſixty foot deep, and yet dry almoſt to the very bottom: For ſuch a one is much leſs ſubject to any kind of alteration, either from the ſettling towards this or that ſide, which moſt Towers and high Buildings, whether new or old, are lyable to: This alſo is ſafe from bending and ſhaking with the wind, which I find the ſtrongeſt Houſes, Towers, and Walls, if of any conſiderable height, are apt to do, nor would the wind have any power to ſwerve the perpendiculars, which 'tis almoſt impoſſible to prevent in high Buildings above ground. But this I can only wiſh it were performed, but cannot hope to have any opportunity of Doing it my ſelf. But certainly the diſcovery of the obſervation will abundantly recompenſe thoſe that have the curioſity to make it.

Having thus reſolved upon the way, and prepared the Inſtruments fit for the obſervation, I began to obſerve the Tranſits of the bright Star in the head of *Draco*; and alwayes both before and after the obſervation, I adjuſted the Menſurator by the Perpendiculars, that I might be the more certain of the exactneſs of the Inſtrument; for I often found that when I came to examine the Inſtrument, a day, or two, or three, or more, after a former obſervation, that there had been wrought a conſiderable change in the Perpendiculars, in ſo much as to vary above a minute from the place where I left them, which I aſcribe chiefly to the warping of the Tube that roſe above the roof of the Houſe, finding ſenſibly that a warm day would bend it conſiderably towards the South, and that a moiſt Air would make it bend from the quarter of the wind: But yet I am apt to think there might be ſomewhat alſo of that variation aſcribable to the whole Fabrick of the Roof, and poſſibly alſo to ſome variation of the Floors; but yet I never found theſe variations ſo ſudden, as to be perceptible in the time of a ſingle obſervation, finding alwayes the preceding and ſubſequent adjuſtings to anſwer.

The firſt obſervation I made was the Sixth of *July*, 1669. when I obſerved the bright Star of *Draco* to paſs the Meridian

Northwards

Northwards of the Zenith point of the Menſurator, at about two Minutes and twelve Seconds.

The ſecond obſervation I made was upon the Ninth of *July* following, when I found it to paſs to the Northwards of the ſaid Zenith or croſs of the Menſurator, near about the ſame place, not ſenſibly differing.

The third obſervation I made upon the Sixth of *Auguſt* following; then I obſerved its tranſitus North of the aforeſaid Zenith, to be about two Minutes and ſix Seconds.

The laſt obſervation I made upon the One and twentieth of *October* following, when I obſerved it to paſs to the North of the Zenith, at one Minute and about 48 or 50 Seconds.

Inconvenient weather and great indiſpoſition in my health, hindred me from proceeding any further with the obſervation that time, which hath been no ſmall trouble to me, having an extraordinary deſire to have made other obſervations with much more accurateneſs then I was able to make theſe, having ſince found ſeveral inconveniencies in my Inſtruments, which I have now regulated.

Whether this Zenith ſo found out upon the Menſurator, be the true Zenith of *Greſham Colledge*, is not in this inquiry very material (though that alſo I deſigned to examine, had not an unhappy accident broken my Object Glaſs before I could comp'eat the obſervation) for whether it were, or were not, it is certain that it alwayes had the ſame poſition to the true Zenith, the Object Glaſs and Perpendiculars having not been in all that time removed out of the Cell, whence if the ſaid Object Glaſs were thicker upon one ſide then upon the other (which is very common and very ſeldome otherwiſe) and conſequently deflected the ray towards the thicker ſide, and ſo made the Perpendicular of the Menſurator to lye on that ſide of the true Perpendicu'ar, that the thicker ſide of the Object Glaſs reſpected, yet it being alwayes ſo if the tranſitus of the Star varied from this falſe Perpendicular, it muſt alſo vary from the true one. The manner how I deſigned to examine and find out the true Perpendicular, is this, which is the way alſo of adjuſting of Teleſcopical ſights, as I ſhall afterwards have occaſion to ſhew. Having marked the four ſides of the Glaſs, the North with N, the Eaſt with E, the South with S, and the Weſt with W, about the firſt

of

of *June* I begin to observe and measure the true distance of some remarkable fixt Star, as of this of *Draco* from the Zenith found one night when the side N of the Glass stood North. Then I change the side of the Object Glass, and put the North side Southwards, and the South, Northwards, and observe the Transitus of the same Star the next night, and note down the same; the third night following I put the East side or E North, and observe the transit of the same Star over the Meridian; and the fourth night I put the West side or W North, and observe the transit of the said Star. Now by comparing all these together, it will be very easie to deduce what the false refraction of the Object Glass is, and which way it lyes, and consequently to regulate the apparent Zenith by the true one. But this only by the by.

'Tis manifest then by the observations of *July* the Sixth and Ninth: and that of the One and twentieth of *October*, that there is a sensible parallax of the Earths Orb to the fixt Star in the head of *Draco*, and consequently a confirmation of the *Copernican* System against the *Ptolomaick* and *Tichonick*.

Before I leave this Discourse, I must not forget to take notice of some things which are very remarkable in the last observation made upon the 21 of *October*. And those were these. First, that about 17 minutes after three a-clock the same day, the Sun being then a good way above the Horizon, and shining very clear into the Room where I lay to observe, and having nothing to screen off the rayes of light, either in the Room where I was, or in the next Room through which I looked, I observed the bright Star in the *Dragons* head to pass by the Zenith as distinctly and clearly as if the Sun had been set, though I must confess it had lost much of the glaring brightness and magnitude it was wont to have in the night, and its concomitants were vanisht: The like I found it divers other dayes before, when I observed it, the Sun shining very cleer into both the aforesaid Rooms, which by the way I suppose was the first time that the fixt Stars were seen when the Sun shin'd very bright, without any obscuring of its light by Eclipse or otherwise. And though we have a great tradition that the Stars may be seen with the naked eye out of a very deep Well or Mine in the day, yet I judge it impossible, and to have been a meer fiction, without any ground: For the being placed at the bottom of a Well doth not at all take away the light of the Atmosphere from affecting the eye in and near the Axis of vision, though

indeed the ſides thereof may much take off the lateral rayes; but unleſs the radiation of the falſe rayes of the Star be brighter then that of the Air, the true rayes from the body are ſo very ſmall, that 'tis impoſſible the naked eye ſhould ever be affected by them. For in the ſecond place, by this obſervation of the Star in the day time when the Sun ſhined, with my 36 foot Glaſs I found the body of the Star ſo very ſmall, that it was but ſome few thirds in Diameter, all the ſpurious rayes that do beard it in the night being cleerly ſhaved away, and the naked body thereof left a very ſmall white point.

The ſmalneſs of this body thus diſcovered does very fully anſwer a grand objection alledged by divers of the great *Anti-copernicans* with great vehemency and inſulting; amongſt which we may reckon *Ricciolus* and *Tacquet*, who would fain make the apparent Diameters of the Stars ſo big, as that the body of the Star ſhould contain the great Orb many times, which would indeed ſwell the Stars to a magnitude vaſtly bigger then the Sun, thereby hoping to make it ſeem ſo improbable, as to be rejected by all parties. But they that ſhall by this means examine the Diameter of the fixt Stars, will find them ſo very ſmall, that according to theſe diſtances and Parallax they will not much differ in magnitude from the body of the Sun, ſome of them proving bigger, but others proving leſs; for the Diameter of the parallactical Circle among the fixt Stars, ſeems to exceed the Diameter of the Star almoſt as much as the Diameter of the annual Orb of the Earth doth that of the Sun. And poſſibly longer and better Teleſcopes will yet much diminiſh the apparent bulk of the Stars by bringing fewer falſe rayes to the eye that are the occaſion of the glaring and magnifying of the ſaid bodies. It may for the preſent ſuffice to ſhew that even with this Glaſs we find the Diameter of this Star conſiderably ſmaller then a Second, and the Parallax we judge may be about 27 or 30 Seconds. It will not therefore be difficult to find many Stars whoſe Diameters ſhall be leſs then a two hundredth part of this Parallax, as poſſibly upon more accurate obſervation this very Star may be found to be. Now we find that the Diameter of the Orb of the Earth is but two hundred times bigger then the Diameter of the Sun in the Center thereof; and therefore if the parallactical difference be found to be two hundred times more then the viſible Diameter of the Star, the Star will prove but of the ſame magnitude with the Sun.

This

This Diſcovery of the poſſibility and facility of ſeeing the fixt Stars in the day time when the Sun ſhines, as I think it is the firſt inſtance that hath been given of this kind, ſo I judge it will be a diſcovery of great uſe for the perfecting Aſtronomy; as firſt, for the rectifying the true place of the Sun in the Ecliptick at any time of the year; for ſince by this means 'tis eaſie to find any Star of the firſt, ſecond, or third magnitude at any time of the day, if it be above the Horizon, and not too near the body of the Sun: And ſince by a way I ſhall ſhortly publiſh any Angle to a Semicircle in the Heavens, may be taken to the exactneſs of a Second by one ſingle obſervator: It will not be difficult for future Obſervators to rectifie the apparent place of the Sun amongſt the fixt Stars to a Second, or very near, which is one hundred times greater accurateneſs, then has hitherto been attained by the beſt Aſtronomers. The like uſe there may be made of it for obſerving any notable appulſe of the ☽, ♃, ♄, ♂, and ♀, to any notable fixt Star that ſhall happen in the day time, which may ſerve for diſcovering their true places and parallaxes. The Refractions alſo of the Air in the day time may by this means be experimentally detected.

I ſhould have here deſcribed ſome Clocks and Time-keepers of great uſe, nay abſolute neceſſity in theſe and many other Aſtronomical obſervations, but that I reſerve them for ſome attempts that are hereafter to follow, about the various wayes I have tryed, not without good ſucceſs of improving Clocks and Watches, and adapting them for various uſes, as for accurating Aſtronomy, compleating the Tables of the fixt Stars to Seconds, diſcovery of Longitude, regulating Navigation and Geography, detecting the proprieties and effects of motions for promoting ſecret and ſwift conveyance and correſpondence, and many other conſiderable ſcrutinies of nature: And ſhall only for the preſent hint that I have in ſome of my foregoing obſervations diſcovered ſome new Motions even in the Earth it ſelf, which perhaps were not dreamt of before, which I ſhall hereafter more at large deſcribe, when further trya's have more fully confirmed and compleated theſe beginings. At which time alſo I ſhall explain a Syſtem of the World differing in many particulars from any yet known, anſwering in all things to the common Rules of Mechanical Motions: This depends upon three Suppoſitions. Firſt, That all Cœleſtial Bodies whatſoever, have an attraction or gra-

vitating power towards their own Centers, whereby they attract not only their own parts, and keep them from flying from them, as we may obſerve the Earth to do, but that they do alſo attract all the other Cœleſtial Bodies that are within the ſphere of their activity; and conſequently that not only the Sun and Moon have an influence upon the body and motion of the Earth, and the Earth upon them, but that ☿ alſo ♀, ♂, ♄, and ♃ by their attractive powers, have a conſiderable influence upon its motion as in the ſame manner the correſponding attractive power of the Earth hath a conſiderable influence upon every one of their motions alſo. The ſecond ſuppoſition is this, That all bodies whatſoever that are put into a direct and ſimple motion, will ſo continue to move forward in a ſtreight line, till they are by ſome other effectual powers deflected and bent into a Motion, deſcribing a Circle, Ellipſis, or ſome other more compounded Curve Line. The third ſuppoſition is, That theſe attractive powers are ſo much the more powerful in operating, by how much the nearer the body wrought upon is to their own Centers. Now what theſe ſeveral degrees are I have not yet experimentally verified; but it is a notion, which if fully proſecuted as it ought to be, will mightily aſſiſt the Aſtronomer to reduce all the Cœleſtial Motions to a certain rule, which I doubt will never be done true without it. He that underſtands the nature of the Circular Pendulum and Circular Motion, will eaſily underſtand the whole ground of this Principle, and will know where to find direction in Nature for the true ſtating thereof. This I only hint at preſent to ſuch as have ability and opportunity of proſecuting this Inquiry, and are not wanting of Induſtry for obſerving and calculating, wiſhing heartily ſuch may be found, having my ſelf many other things in hand which I would firſt compleat, and therefore cannot ſo well attend it. But this I durſt promiſe the Undertaker, that he will find all the great Motions of the World to be influenced by this Principle, and that the true underſtanding thereof will be the true perfection of Aſtronomy.

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ANIMADVERSIONS

On the first part of the

MACHINA COELESTIS

Of the Honourable, Learned, and deservedly Famous

Astronomer

JOHANNES HEVELIUS.

CONSUL OF

DANTZICK;

Together with an Explication of some

INSTRUMENTS

MADE BY

ROBERT HOOKE, Professor of Geometry in *Gresham College*, and Fellow of the *Royal Society*.

LONDON,

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